LIMNOLOGY OF SOME WETLANDS OF ALIGARH REGION

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

ZOOLOGY

BY

SYEED AHMAD UNTOO

FISHERIES AND AQUACULTURE SECTION
DEPARTMENT OF ZOOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

2002

Dedicated To
My
Parents And Teachers

Dr. Asif A. Khan
M.Sc., Ph.D. (Alig), F.Z.S.I.. F.A.E.B.

Professor
Department of Zoology
Aligarh Muslim University,
ALIGARH-202002

Res. : Gulmarg Colony,
Girls College Road,
Lal Diggi,
ALIGARH-202001
Phone : 0571-400569

Dated.............................

CERTIFICATE

*This is to certify that the work presented in this thesis entitled #**Limnology of some wetlands of Aligarh region.**# by **Mr. Syeed Ahmad Untoo** incorporates the results of his independent study carried out under my supervision. I strongly believe that this work fulfils the gap in the knowledge on the limnology of wetlands. He is allowed to submit this thesis for the award of **Ph.D**. degree in **Zoology** of **Aligarh Muslim University, Aligarh.***

(*Asif A. Khan*)

CONTENTS

ACKNOLEDGEMENTS

By the grace of God, I am highly privileged to express my abiding sense of obligation to my affectionate, revered and gifted teacher, my research guide, ***Dr. Asif A. Khan***, *Professor of Zoology, Aligarh Muslim University, Aligarh,* whose sagacious and invaluable guidance was instrumental in the completion of this work I have been filled with such revered feelings that suddenly words have lost meanings and sentences are becoming feeble to bear the burden to express the benefits of his help and counsel over the entire period of time to bring the present work on the horizon. Sir, with my utmost gratitude, I thank you from the core of my heart for all the trouble you took in solving my problems during my research

I am indebted to ***Prof. Jamil A. Khan,*** *former Chairman and* ***Prof. A.K. Jafri***, *present Chairman, Department of Zoology, Aligarh Muslim University, Aligarh* for encouraging me, for providing necessary laboratory facilities and for giving wise suggestions

I would like to put on record my heartfelt thanks to ***Prof. Shahid H. Khan, Prof. (Mrs.) D.S. Jairajpuri, Prof. Absar M. Khan Prof. M. Hayat, Prof. Shujauddin, Prof. Humyaun Murad, Dr M. Shahid Siddiqui*** *and* ***Dr Absarul Husnain*** for giving me constant encouragement and suggestions whenever needed

I wish to convey my warmest indebtedness and a special word of thanks to ***Dr. Mukhtar A. Khan*** *and* ***Dr. Asim Azfer*** for their useful suggestions, encouragement, inspiration and every kind of help during the course of my work

From the depth of my heart, I am grateful and appreciate the manyfold help and cooperation rendered to me by my friends, seniors and especially my laboratory colleagues, ***Ms. Saltanat Parveen*** *and* ***Ms. Shazia Ansari*** at the time of need

I wish to express my heartfelt and deepest gratitude to my ***parents, sister, brother and granny*** for their everlasting moral support, affection, love, patience and forbearance without which it would have been impossible for me to accomplish the task of completing this work

I have been fortunate enough to get many classical research publications/papers generously provided by many esteemed scientists within and outside India, their contribution to this work is gratefully acknowledged

I am also thankful to my friend, ***Mr. Rais A. Khan,*** for typing and shaping the manuscript.

Syeed Ahmad Untoo

(SYEED AHMAD UNTOO)

Chapter I

GENERAL INTRODUCTION

INTRODUCTION

Water is an extremely important resource for humans and all other forms of life. It is one of the most important resources and the first creation on the earth. It attracted all the early civilizations around it, the live illustrations are the Babylon around Euphrates, Egypt around Nile, Chinese on Yangtze Kiang and India on the Indus - Ganga basin. River valleys and their associated flood plains have served as the centres of human population since earliest times. Even today, the wetlands, which nurtured the greatest civilisations of Mesopotamia and Egypt, and of the Niger, Indus, and Mekong valleys, continued to be essential to the health, welfare and safety of the people who live in or near them (Maltby, 1986 and Dugan, 1990).

There is ever-growing demand for water with explosion of population growth, rapid urbanisation etc. The severity of crises is further intensified with the indiscriminate use of water resources. It has already been argued that by the end of 2010, more than 300 million people living in 26 countries mostly in Africa and Middle East will have to face extreme water crisis (Pedric, 1994).

The problems of the environment have increased many folds in the last fifty years and some of them have become persistent. The increasing need to study the aquatic environment has become need of the hour, even imperative to be able to manage to the environment so that it is protected and preserved.

Freshwater habitats are kaleidoscopic as the land itself. Since the time immemorial, fresh waters have always been of vital importance to man and is interesting to note that his early habitation was within easy reach of wetlands, ponds, lakes and rivers. Man's primary concern with water was drinking, food and means of washing and cleaning, but he realised later the inherent mysteries of aquatic environment and its beauty to form basis for all life activities.

India, a land of diversity, is rich in natural resources and agriculture. The economy of the country is agricultural based and self sufficient in food grains. The climate ranges from tropical in Southern to temperate in Northern regions. The landscape includes the towering mountains, alluvial plains, plateaus, deserts, costal plains, oceans, rivers, deltas and wetlands (Gopal, 1995).

Wetlands are generally small in area, shallow and rain fed. They perform some useful functions in maintaining ecological balance of the nature (WWF, 1987). They also occur extensively throughout the world in all climatic regions and are estimated to cover about 6% of the earth's surface. They also occur in all shapes and sizes ranging from less than one hectare to hundreds of square kilometres in area (Sugunan, 1995, 1997). These wetlands show a wide spectrum of habitats ranging from extensive peat bogs of northern regions to tropical mangrove forests; from seasonal ponds and marshes to flood plains and permanent riparian swamps; from fresh water ponds, shallow lakes and large reservoirs to salt lakes, brackish lagoons, estuaries and coastal salt marshes. Extensive beds of marine algae along the sea coasts and coral reefs are also considered as wetlands (Gopal, 1995). Thus wetlands exhibit very large differences in their habitat characteristics such as hydrological regimes and bottom soil quality and in the nature and diversity of their biota. Therefore, it is equally difficult to classify wetlands into different types.

More than fifty schemes of classification have been proposed for wetlands in different countries and there is hardly any one that satisfies all scientific criteria and is also practically not applicable in the field. The most comprehensive and elaborate hierarchical system of classification has been developed by Cowardain *et al.* (1979) for the United States Fish and Wildlife (Table 1). The simplest classification is one proposed by Scott (1989) for use in *Ramsar Database* and followed in the directory of Asian Wetlands (Scott 1989a). It recognises simply 22 wetlands types listed in Table 2. Gopal and Sah (1995) have also proposed a scheme of classification of Indian wetlands as given in Table 3.

Dugan (1990) suggested a scheme of classification, which is very similar to the Cowardin's system. He groups the wetlands into salt water, freshwater and man-made wetlands. These are further subdivided into categories based on their hydrological characteristics (Table 4).

This scheme is relatively simple and practical. Ramsar convention, at the fourth conference of the contracting parties, adopted a simple classification system of wetlands types for the description of Ramsar sites (Davis, 1994). The system recognizes 35 types grouped under three major categories: *marine and coastal wetlands, inland wetlands and man-made wetlands.*

Most of these types are artificial and a heterogenous assemblage, like the category of fresh water ponds, marshes and swamps is different from shrimp ponds, fish ponds on one hand and from swamp forest, temporarily flooded forests on the other hand. The rice paddies are distinguished from "flooded arable land" whereas the salt pans and salt lakes are recognised as different types. This classification has been followed by the revised Directory of Indian Wetlands (WWF/AWB, 1993).

A number of ecologists, limnologists, and geochemists have tried to define wetland enigmatic ecosystem, but only few of these definitions have gained limited acceptability (WWF, 1992). In spite of the global attention currently focused on the wetland ecosystem, there is yet no single universally accepted definition of wetland. The main cause of this is diversity of wetland types and the difficulty in demarcating the boundaries of this ecosystem. (WWF, 1992). The IUCN defined wetlands very broadly for the purpose of the Ramsar convention on the wetlands of international importance (IUCN, 1971) as *"areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary with water that is static or flowing, fresh, brackish or salt, including areas of marine water depth of which at low tide does not exceed six meters".* Some inventories used qualified Ramsar definition, which excluded coral reefs and other exclusively marine systems (Scott, 1989). Wetlands have also been defined as, *"swamps and other damp areas of land but in common parlance the word is used inter changeable with lake which donates a large water body surrounded by land"* (Oxford Dictionary, 1990).

According to Cowardain *et al.* (1979) *"the wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually aquatic at or near the surface, or the land is covered by shallow waters."* The recent *Directory of Important Wetlands in Australia* (Usback and James, 1993; ANCA, 1996) used the same definition. Cowardin *et al.* (1979) have recommended that for purposes of this classification wetlands must have one or more of the following three attributes: *1) at least periodically, the land supports predominantly hydrophytes, 2) the substrate is predominantly undrained hydric soil, and 3) the substrate is nonsoil and is saturated* *with water or covered, by shallow water at sometime during the growing season of each year.*

Cowardain *et al.* (1979) further elaborated to delimit wetland areas. According to them, wetland includes a variety of areas that fall into one of the following five categories.

1. Areas with hydrophytes and hydric soils, such as those commonly known as marshes, swamps, and bogs;
2. Areas without hydrophytes but with hydric soils for example, flats where drastic fluctuations in water level, wave action, turbidity, or high concentration of salts may prevent the growth of hydrophytes.
3. Areas with hydrophytes but no hydric soils, such as margins of impoundments or excavation where hydrophytes have become established but hydric soils have not yet developed.
4. Areas without soils but with hydrophytes such as the seaweeds-covered portion of rocky shores.
5. Wetlands without soil and without hydrophytes, such as gravel beaches or rocky shores without vegetation.

The definition was further clarified by setting the boundary of wetland with both the terrestrial and deep-water habitats. The boundary with deep-water habitats is more important in the context of IUCN definition and management of wetlands. According to Cowardin *et al.* (1979), "*The boundary between wetland and deep water habitat in the marine and estuarine system coincides with the elevation of the extreme low water of spring tide; permanently flooded areas are considered deep water habitats in these systems. The boundary between wetland and deep-water habitat in the Riverine, Lacustrine and Palustrine systems lies at a depth of 2 m below low water, however, if emergents, shrubs or trees grown beyond this depth at any time, their deep-water edge is the boundary*".

This definition, despite its limitations for practical use, is widely used by wetland scientists. To over come the difficulty in deciding whether a plant is a hydrophyte or not, the U.S. Fish and Wildlife Service prepared a list of hydrophytes for identifying wetland (Gopal, 1995).

The U.S. Corps of Engineers defined wetlands as "*those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support a prevalence of vegetation typically adapted for life in saturated soil conditions.*" (Chaudhuri, 1989).

Despites a number of National/Regional wetland surveys (McComb and Lake, 1988; Finlayson and von Oertzen, 1993; Jacobs and Brock, 1993), there is no standard definition in Australia (Pressey and Adam, 1995).

A further definition adopted by Bunn *et al.* (1997) who also undertook a national overview of wetlands and defined them as "*land permanently or temporarily under water or water lodged. Temporary wetlands must have surface water or water lodging of sufficient frequency and / or duration to affect the biota. Thus the occurrence, at least sometimes, of hydrophytic vegetation or use by water birds are necessary attributes*".

Once the generally accepted categories are exhausted, defining 'wetlands' becomes a tediously legalistic business, depending on the usage of local lawmakers, authorities or conservation groups. The U.S. Fish and Wildlife Service does not define permanently flooded deepwater areas as wetlands. These zones, generally deeper than 1.8 meters, are defined as '*deepwater habitats*', "since water and not air is the principal medium in which dominant organisms must live" (Tinner, 1984). Shallow lakes and ponds are considered wetlands by many authorities, and some include coastal waters to a depth of six meters. Thus reefs and aquatic beds of plants such as eelgrass (*Zostera*) and seagrass (*Thalassia*) would fall into this wide definition. There are also wetlands which may have no higher vegetation at all, like rocky shores and bottoms; shores of mud, silt or sand; and stream and riverbeds (Maltby, 1986)

In India, there is no single word equivalent to wetland. Of course, no language has one word to define this complex ecosystem. The marshes are known as *Chaurs* in Bihar and *Bhils* in Assam and Northeast. Large shallow lakes and ponds are called as *Tals* in Uttar Pradesh and Madhya Pradesh. The terai region in the foothills of the Himalayas in also dominated by marshes and swamps. Thus, there is much confusion as to what a swamp, marsh, wetland or a lake is. Finlayson and Rea (1999), have suggested that local needs and processes would influence the choice of definitions.

Unfortunately, rapid urbanisation has lead to the loss of wetland habitat through encroachment, bad management and pollution from sewage and waste and litter disposal activities. These factors have seriously affected the survival of these water bodies and posed serious threat to the flora and fauna supported by them. Water quality, habitat structure, flow regime, energy source and biotic interactions are the major environmental factors that determine resource integrity (Karr, 1991). The physical and chemical attributes of water are the critical components of a water resource. Their dynamics may be complex and changing, depending upon other constituents in the geological strata, soil, topography and land use in the region (EPA, 1990).

Gopal *et al.* (1982), Larson (1982), Adamus and Stockwell (1983), Sather and Smith (1984), Dugan (1990) and Sather *et al.* (1990) have discussed at length the functions and values of wetlands. There have been few efforts to model wetlands (Conger, 1971 and Hindall, 1975). In order to establish the value of wetlands we must identify and quantify the hydrobiological functions that wetlands perform. Some of the urgent research needs for identifying and quantifying hydrobiological functions are:

a) The need to improve, refine and perhaps simplify the existing techniques for various measurements of wetlands,
b) The need to improve over basic understanding of and to quantify the soil-water vegetation relationships of wetlands,
c) The need to make in-depth, long term monitoring studies of different wetland types under different environmental conditions, and
d) The need to continue developing models based on hydrologic data so that we have better analysis and predictive capacity.

These can be improved or modified to study wetlands specifically taking into consideration the amount of error involved in the determination of various physical, chemical and biological components.

On a global scale, several international organizations are expanding their wetland activities like IUCN,WWF and IWRB. Wetlands being low-lying areas have capacity to detain and retain water. This function bestows upon value for flood control, a flood mitigation and aquifer recharge (Gopal *et al.,* 1982). Wetlands provide people, directly or indirectly, with enormous range of goods and services like staple food plants, fertile grazing land, support for coastal and inland fisheries, flood control and breeding grounds for waterfowl and fish etc. Flood control water purification and shoreline stabilization can all be maintained by wetland systems. However, most wetland development projects today concentrate intensively on one aspect such as agriculture or fishery yield (Dugan, 1990).

Two third of the fish we eat depend upon the wetlands at some stages in their life cycle. The nutrient rich sheltered habitats of wetlands are used by fish for spawning as nursery areas or habitats for adults. Wetlands are also important as genetic reservoir for certain species of plants. They act as living laboratories, serving as gene pools of valuable life forms, which provide wild, resistant genotypes of many of our present and future crops. They are also sources of raw compounds of known and unknown medicinal values. Rice, a common wetland plant, is the staple diet of over half of the worlds people population, (Dugan, 1990). Many wetlands are lush habitats that provide countless species of plants and animals with a rich environment from which they can obtain most of their requirements. However, as strange as it may sound, the relationship between wetlands and water is not always simple and uniform.

One of the most valuable functions of wetlands is the cleansing and detoxification of polluted waters. In a heavily populated country such as India where most epidemics may be attributed to polluted waters and poor sanitation and where industrialization has resulted in the heavy metals build-up in lakes and rivers, this function of wetland assumes particular significance The best example is the wetlands around Kolkata which help the city to survive (Agarwal and Chak, 1991).

During the dry months, wetlands serve as storage reservoirs, which sustain human communities living on the periphery providing them water for domestic consumption, irrigation and industrial use. Being aware of these functions of wetlands, human communities, especially in parts of India where there is marked seasonality of rainfall, have traditionally created wetlands to collect and store water for recharging and consumption (Sivanappan, 1990). Plentiful water and a high productivity have made wetlands among the richest and most biologically diverse ecosystems in the world (WWF, 1992). Many wetlands in India support spectacular concentrations of wildlife (Scott 1989a). Birds belonging to 318 species are found associated with Indian wetlands (Vijayan, 1986)

Apart from birds, wetlands provide refuge to a wide variety of other faunal and floral species like mammals, reptiles, amphibians, insects, fish and a multitude of water loving plants. Many species of wetland flora and fauna act as *bio-indicators*, showing extreme sensitivity to any deterioration in the quality of the environment like algal, ciliates and macrophytes which have been used as indicator organisms to assess the level of pollution in a water body. (Wu, 1999)

To formulate sound scientific management measures for augmenting fish and fisheries production in wetlands, the knowledge of limnology is must. This would provide clues to the production potential of such ecosystems and would help in setting targets of fisheries resource from such wetlands. Many other reasons have contributed to wetland as being attractive objects of study by workers around the globe. Among these are their relatively large number; seasonally related to monsoon and hot and dry summers; proximity and easy accessibility.

Welch (1952) defined limnology as "*the branch of science, which deals with the biological productivity of inland waters and with all the causal influences, which determine it*". Limnology has been a subject of interest ages before. Most of the limnological researches have conducted by person associated with permanent centres for limnological studies both in India and outside India.

Important contributions in the field of limnology are those of Birge and Juday (1911, 1929), Atkins (1923), Maùcha (1932), Mortimer (1941), Chandler (1944), Rodhe (1948), Ganapati and Chacko (1951), Welch (1952), Chacko and Krishnamoorthy (1954), Das and Srivastava (1956, 1959), Hutchinson (1957, 1967, 1975, 1975a), Reid (1961), Ruttner (1963), Hynes (1963, 1964), SubbaRao and Govind (1964), Verma (1964), Zafar (1964, 1966), Michael (1965, 1969), Munawar (1966, 1970), Khan and Qayyum (1966a, b), Seetharamaiah (1966), Husainy (1967), Vasisht (1968), Vyas and Kumar (1968), Verma and Shukla (1968, 1970), Sahai and Sinha (1969), Sumitra (1969), Khan (1969), Das (1970), Saha *et al.* (1971), Unni (1971, 1972, 1982 and 1984), Moitra and Mukherji (1972), Saksena and Adoni

(1973), Jana (1973, 1974), Gosh *et al.* (1974), Nasar and Munshi (1975), Vasisht and Sharma (1975), Wetzel (1975), Zutshi and Khan (1977), Khan *et al.* (1978), Bohra *et al.* (1978), Ali and Khan (1979), Jyoti and Sehgal (1979), Swarup and Singh (1979), Fernando (1980, 1984), Sharma and Saksena (1981), Saksena and Sharma (1981), Zutshi (1981), Datta *et al.* (1983, 1984), Cole (1983), Goldman and Horne (1983), Thukral *et al.* (1983), Wetzel (1983), Chattopadhya *et al.* (1984), Raina *et al.* (1984), Arora *et al.* (1985), Chourasia and Adoni (1985), Khan and Khan (1985), Hedge (1985), Hosetti *et al.* (1985), Singh and Bhowmick (1985), Singh *et al.* (1985), Tripathi and Serevastava (1985), Reddy and Venkateshwarlu (1986), Yousuf *et al.* (1986), Saksena *et al.* (1986), Sarkar *et al.* (1986), Yousuf *et al.* (1986), Anantharaj *et al.* (1987), Bernice *et al.* (1987), Kulshreshtha *et al.* (1987), Sharma and Michael (1987), Tripathi *et al.* (1987), Haque *et al.* (1988), Singh (1990), Hails (1996, 1997), Gaur, (1998), Vijaykumar (1999), Untoo *et al.* (2001), Khan *et al.* (2002) and Kumar (2002).

Our knowledge on the limnology of wetland in India is still fragmentary. Important contributions made in India pertaining to limnological studies on wetlands are those of Gopal (1982, 1982a, 1990, 1995, 1999), Trisal and Zutshi (1985), DeSilva (1988) Vyas and Garg (1989), Vijayan (1991 and 1994), Chatrath (1992, 1992a), De Roy (1992), De Roy and Thandan (1992), Jerath (1992), Narayanan (1992), Trisal (1992), WWF (1992), Bhandary (1993), DeRoy and Hussain (1993), Gopal *et al.* (1993), WWF and AWB (1993), Biswas and Trisal (1993). Gopal and Krishnamurthy (1993), Gopal (1995), Gopal and Sah (1995), Chaudhuri (1998), Gaur *et al.* (2001). Very recently, Dayananda *et al.* (2002) and Hosetti (2002) have also reviewed the problems of wetlands and the strategies adopted for their conservation and management.

The long way is to be crossed in understanding the different aspects of limnology of these wetlands. It is evident from the above-mentioned literature, that dynamics of water bodies, large or small, is governed by the seasonal fluctuations typical to tropical areas, as that of our country. Thus the complete knowledge of the various limnological parameters of wetlands have great importance in the context of the present day stress on these environments. Naturally, under such circumstances, the limnology assumes great significance in understanding the ecological status of such peculiar water bodies. In most respects limnological knowledge of lakes is much more advanced than that of wetlands. In fact for wetlands, it is fragmentary often altogether lacking in some aspects and scattered in the literature.

Scientist who monitor and study wetlands present their data and results to wetland managers and others for wetland conservation and management. An exhaustive account of wetland characteristics has been given by Mitsher and Gosselink (1993). Patten *et al.* (1990) and Finlayson (1996a, c, d) have illustrated the multifaceted nature of wetlands management and monitoring and argued that monitoring of wetlands is not just technical exercise resulting in the collection of environmental data.

Studies conducted in Australia (Mc Comb and Mc Comb, 1967; Atkins *et al.*, 1977; Farrell *et al.*, 1979; Finlayson *et al.*, 1980, 1984a, b; Blair and Finlayson, 1981; Finlayson and Mitchell, 1981; Gordon *et al.*, 1981 and Finlayson and Gillies, 1982) indicated that accumulation of knowledge from such studies has given poor state of information for many wetlands. In addition, a lot of work has been done on the wetlands outside India by Verry (1975), Good *et al.* (1978), McCormick (1978), van der Valk and Davis (1978), Cowardin *et al.* (1979), Greenson *et al.* (1979), Jaworski *et al.* (1979), Finlayson *et al.* (1980 ,1998), Larson *et al.* (1980),Vander Valk (1981), Larson (1982), Swarbrick *et al.* (1982), Adamus and Stockwell (1983),Hocking *et al.* (1983), Bardecki (1984), Anon (1986, 1995), Keddy (1986, 1991, 1999, 2000), Maltby (1986), Adams (1988), McComb and Lake (1988), NWWG (1988), Bolen *et al.* (1989), IWRB (1989), Keddy and Wisheu (1989), Leck (1989), Moore *et al.* (1989), Moore and Keddy (1989),Scott (1989), Scott and Poole (1989), Dugan (1990), Levine and Willard (1990), Patten *et al.* (1990), Barson and William (1991), Adamus (1992,1996), Hollis (1992), Hollis *et al.* (1992), Boutin and Keddy (1993), Finlayson and von Oertzen (1993), Hussain (1993), Jocoba and Broch (1993), Keddy *et al.* (1993), Matthews (1993), Mitsher and Gosselink (1993), Shirazi (1993), Usback and James (1993), Zarull and Mudroch (1993), Campbell (1994), Mitchell *et al.* (1994), Ellison and Bedfold (1995), Finlayson and van der Valk (1995), Han Sanghoo (1995), Pollock (1995), Pressey and Adam (1995), Lu (1990, 1995), Weiher and Keddy (1995), Wilen and Bates (1995), ANCA (1996), Doods *et al.* (1996), Hollis and Finlayson (1996), Finlayson (1996a, b, c, d), Jonauskas (1996), Racey *et al.* (1996), Weiher *et al.* (1996), Bunn *et al.* (1997), Storrs and Finlayson (1997), Ramsar Convention Bureau (1997), Wibowo and Suyatuo (1997), Kingsford (1998), Finlayson and Rea (1999), Finlayson and Mitchell (1999), Mayer and Galatowitsch (1999), Mayer *et al.* (1999), Rea and Storrs (1999), Conley (2000), Doods and Welch (2000), Keddy and Fraser (2000), Pirot *et al.* (2000), Kemp and Doods (2001) and McLaughlin and Brindle (2001).

Aligarh is one of the famous districts of Uttar Pradesh, which is bestowed with a series of wetlands showing remarkable variations with regard to their nature and biota. The region harbours a large number of wetlands, which are unique in more than one way. These biotopes are exposed to different seasons with varying hot and cold conditions of the region.

Many of these wetlands are seasonal, while few are perennial. The seasonal one are formed by digging the soil for the construction of road and household purposes. They were made mainly for collecting rainwater for irrigation, cattle bath, washing , fish farming, angling and other recreation purposes.

The emphasis should be on the importance of wetlands and how their conservation can be achieved. Several factors have contributed to make preliminary limnological study of these wetlands of Aligarh and present the data on the aspects, like physico-chemical and biological characteristics. For the present study, three important wetlands were selected from Aligarh region, namely *Medical pond* (MP), *Chharat ponds* 1 and 2 (CP-1, CP-2).

In the present investigations, the main objective was to evaluate water quality of these three untouched wetlands of Aligarh region, and to study the environmental stress on these wetlands with varying limnological characteristics. This will put a record for academic, scientific and research needs for future generation.

The detail objectives of the present work include:

1. To monitor various physico-chemical and biological characteristics which could assess the trophic status of these wetlands.

2. The data obtained on physico-chemical and biological characteristic would help to formulate diversity of the wetlands.
3. To find out the sources of pollution.
4. To find the relationship between different physical, chemical and biological parameters.
5. To assess the water quality index in these wetlanas.

Table 1.
Hierarchical classification of wetlands and deepwater habitats as given by Cowardin *et al.* (1979).

	System	Subsystem	Class
WETLANDS AND DEEP WATER HABITATS	Marine	Subtidal	Rock Bottom Unconsolidated Bottom Aquatic Bed Reef
		Intertidal	Aquatic Bed Reef Rocky Shore Unconsolidated Shore
	Estuarine	Subtidal	Rock Bottom Unconsolidated Shore Aquatic Bed Reef
		Intertidal	Aquatic Bed Reef Streambed Rocky Shore Unconsolidated Shore Emergent Wetland Scrub-Shrub Wetland Forest Wetland
	Riverine	Tidal	Rock Bottom Unconsolidated Bottom Aquatic Bed Rocky Shore Unconsolidated Shore Emergent Wetland
		Lower Perennial	Rock Bottom Unconsolidated Bottom Aquatic Bed Rocky Shore Unconsolidated Shore Emergent Wetland
		Upper Perennial	Rock Bottom Unconsolidated Bottom Aquatic Bed Rocky Shore Unconsolidated Shore
		Intermittent	Streambed
	Lacustrine	Limnetic	Rock Bottom Unconsolidated Bottom Aquatic Bed
		Littoral	Rock Bottom Unconsolidated Bottom Aquatic Bed Rocky Shore Unconsolidated Shore Emergent Wetland
	Palustrine		Rock Bottom Unconsolidated Bottom Aquatic Bed Unconsolidated Shore Moss-Lichen Wetland Emergent Wetland Scrub-Shrub Wetland Forested Wetland

Table 2
Wetland types initially recognized by the Ramsar Convention (Scott, 1989)

No.	Wetlands Types
1.	Shallow sea bays and straits (under six meters at low tide)
2.	Estuaries, deltas
3.	Small offshore islands, islets
4.	Rocky sea coasts, sea cliffs
5.	Sea beaches (sand, pebbles)
6.	Intertidal mudflats, sand flats
7.	Mangrove swamps, mangrove forest
8.	Coastal brackish and saline lagoons and marshes
9.	Salt pans (artificial)
10.	Shrimp ponds, fish ponds
11.	Rivers, streams – slow flowing (lower perennial)
12.	Rivers, streams – fast flowing (upper perennial)
13.	Oxbow lakes, riverine marshes
14.	Freshwater lakes and associated marshes (lacustrine)
15.	Freshwater ponds (under 8 ha), marshes, swamps (palustrine)
16.	Salt lakes, saline marshes (inland drainage systems)
17.	Water storage reservoirs, dams
18.	Seasonally flooded grassland, savanna, palm savanna
19.	Rice paddies
20.	Flooded arable land, irrigated land
21.	Swamp forest, temporarily flooded forest
22.	Peat bogs

Table 3.
Classification of wetlands as proposed by Gopal and Sah (1995)

<table>
<tr><td rowspan="2">TIDAL WETLANDS</td><td colspan="2">Woody vegetation</td><td>i. Permanently flooded (or waterlogged)
Mangroves
Mangrove scrub
Saltwater mixed forest (Heritiera)
Brackishwater mixed forest (Heritiera)
Palm swamp (Nypa)
ii. Seasonally flooded (or waterlogged)
Saline scrub</td></tr>
<tr><td colspan="2">Herbaceous vegetation (mostly submerged)</td><td>i. Permanently flooded (or waterlogged)
Coastal beds of kelps and seagrasses
Lagoons
Estuaries and Backwaters
ii. Seasonally flooded (or waterlogged) (may include areas flooded by very high tides)</td></tr>
<tr><td rowspan="4">INLAND WETLANDS</td><td rowspan="2">SALINE WETLANDS</td><td>Woody vegetation</td><td>i. Permanently flooded (or waterlogged)
There are none.
ii. Seasonally flooded (or waterlogged)
Saline scrub</td></tr>
<tr><td>Herbaceous vegetation (submerged or other halophytes)</td><td>i. Permanently flooded (or waterlogged)
Saline high altitude lakes
(in most cases Littoral zones only)
ii. Seasonally flooded (or waterlogged)
Salt lakes</td></tr>
<tr><td rowspan="2">FRESHWATER WETLANDS</td><td>Woody vegetation</td><td>i. Permanently flooded (or waterlogged)
Myristica swamp
Submontane hill valley swamp
Creeper swamp (including cane brakes)
ii. Seasonally flooded (or waterlogged)
Eastern seasonal swamp
Barringtonia swamp
Syzygium cumini swamp low forest
Seasonal Dillenia swamp
Riparian fringing forests
Alder forests
Riverine blue pine forests
Wet bamboo brakes</td></tr>
<tr><td>Herbaceous vegetation</td><td>i. Permanently flooded (or watrerlogged)
Submerged and/or floating leaved
Cattails (mainly Typha angustata)
Reeds
Tail emergents (other than reeds and cattails)
Tail sedges
Short sedges and grasses
Wet meadows
ii. Seasonally flooded (or waterlogged)
Submerged and/or floating leaved
Cattails (mainly Typha elephantine)
Reeds
Tall emergents (other than reeds and cattails)
Tall sedges
Short sedges and grasses
Wet meadows
Tall grasses</td></tr>
</table>

Table 4
Wetland classification suggested by Dugan (1990)

1. SALT WATER		
1.1. Marine	Subtidal	i) Permanent unvegetated shallow waters loss than 6m depth at low tide, including sea bays, straits. ii) Subtital aquatic vegetation, including kelp beds, sea grasses, tropical marine meadows iii) Coral reefs
	Intertidal	i) Rocky marine shores, including cliffs and rocky shores. ii) Shores of mobile stones and shingle. iii) Intertidal mobile unvegentated mud, sand and salt flats. iv) Intertidal vegetated seadiments, including salt marshes and mangroves, on sheltered coasts.
1.2 Esturine	Subtidal	i) Estuarine waters; permanent waters of estuaries and estuarine systems of deltas.
	Intertidal	i) Intertidal mud, sand or salt flats, with limited vegetation. ii) Intertidal marshes, including salt-marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes. iii) Intertidal forested wetlands, including mangrove swamp, *Nipa* swamp, tidal freshwater swamp forest.
1.3 Lagoonar		i) Brackish saline lagoons with one or more relatively narrow connections with the sea.
1.4 Salt lake		i) Permanent and seasonal, brackish, saline or alkaline lakes, flats and marshes.
2. FRESH WATER		
2.1 Riverine	Perennial	ii) Permanent rivers and streams, including waterfalls. iii) Inland deltas.
	Temporary	i) Seasonal and irregular rivers and streams. ii) Riverine floodplains, including river flats, flooded river basins, seasonally flooded grasslands.
2.2 Lacustrine	Permanent	ii) Permanent freshwater lakes (>8 ha). iii) Permanent freshwater ponds (<8 ha).
	Seasonal	ii) Permanent freshwater marshes and swamps on inorganic soils, with emergent vegetation whose bases lie below the water table for a least most of the growing season. iii) Permanent peat-forming freshwater swamps, including tropical upland valley swamps dominated by *Papyrus* or *Typha*. iv) Seasonal freshwater marshes on inorganic soil, including sloughs, potholes, seasonally flooded meadows, sedge marshes and bamboos. v) Peatlands, including acidophilous, ombrogenous, or soligenous mires covered by moss, herbs or dwarf shrub vegetation, and fens of all types. vi) Alpine and polar wetlands, including seasonally flooded meadows moistened by temporary waters from snowmelt. vii)Freshwater springs and oases with surrounding vegetation. viii) Volcanic fumaroles continually moistened by emerging and condensing water vapour.
	Forested	i) Shrub swamps, including shrub-dominated freshwater marsh, shrub carr and thickets on inorganic soils. ii) Freshwater swamp forest, including seasonally flooded forest, wooded swamps on inorganic soils. iii) Forested peatlands, including peat swamp forest.
3. MAN-MADE WETLANDS		
3.1 Aquaculture/Mariculture		ii) Aquaculture ponds, including fish ponds and shrimp ponds.
3.2 Agriculture		ii) Ponds, including farm ponds, stock ponds, small tanks. iii) Irrigated land and irrigation channels, including rice field, canals and ditches. iv) Seasonally flooded arable land.
3.3 Salt Expoitation		*ii) Salt pans and salines.*
3.4 Urban/Industrial		i) Excavations, including gravel pits, borrow pits and mining pools. ii) Wastewater treatment areas, including sewage farms, settling ponds and oxidation basins.
3.5 Water-storage areas		i) Reservoirs holding water for irrigation and/or human consumption with a pattern of gradual, seasonal, draw down of water level. ii) Hydro-dams with regular fluctuations in water level on a weekly or monthly basis.

Chapter II

DESCRIPTION OF THE WETLANDS

DESCRIPTION OF THE STUDY AREA

Wetlands directly or indirectly have an enormous ecological, commercial and socio-economic importance and values, which are rich in components of *bio-diversity*, life, flora and fauna of important local, natural and regional significance (Gopal, 1995).

Aligarh and its adjoining areas are richly well off with wetlands which support an extensive and regular fisheries of various kinds. They are surrounded by two river systems, Ganga and Jamuna with their many tributaries.

In the present investigations three waterbodies have been selected as wetlands to study their limnology, namely *Medical pond (MP), Chharat Pond* 1 (CP-1) *and Chharat Pond* 2 (CP-2).

Medical Wetland : The medical pond, locally termed as *Dhobi ghat* (Fig. B, Plate1), is a perennial fresh water sewage fed wetland, situated at a distance of about 2 kms from university campus. It has achieved golden Jubilee in its age and is almost rectangular in shape. It is a shallow eutrophic wetland covering an area of about 0.57 hect. with its depths varying from 1.50 m during monsoon to 0.60 m during summer. Its source of replenishment is mainly rainwater which enters as a surface run-off during rainy season and through a drain coming from the adjacent locality and the overhead tank (Plate 2).

On one side it has a luxurious growth of Babul (*Acacia arabica*) and some Neem (*Azadirachta indica*) trees. These trees thus deprive this wetland from early sunlight at certain places during early hours of the day. Considerable litter from these plants is also deposited in this wetland, but no aquatic weed is found in this wetland.

This wetland is used as a drainage basin into which drainage water sweeps from the surrounding locality and also for bathing and washing purpose. Organic nutrients are added in the pond through a drain, which bring sewage from adjacent locality. Many washermen use this wetland for washing the clothes, thus adding certain chemicals and colours to its water almost every day that brings certain physico- chemical and biological changes in its flora and fauna regularly.

Bottom of the wetland contains mostly lose mud, sand, stones, part of dead plants, dead plankton and decayed litter deposited in this wetland through trees on its bank. The colour of the soil varies from grey to brown and black during different seasons of the year (Table 6).

The water of this wetland is turbid due to luxuriant growth of microscopic algae and the colour or stains of the washing chemicals used by washermen. Its main fish inhabitants are air breathing fishes, like *Esomus danricus, Heteropneustes fossilis, Clarias batrachus, Channa punctatus and Colisa fasciatus*. along with other aquatic organisms like frogs, water snakes, worms and certain tortoises etc. which were encountered during the course of study.

Chharat Wetlands: These wetlands are age-old water bodies having irregular shore line (*Dendritic* type). Locally they are known as *Tallaiyas* by the villagers. They are situated very close to each other and gets connected with each other during rainy season due to over flooding of the area otherwise remain quite separate except at a point where they are joined by a big drain pipe as shown in Fig. A.

They are situated about 8 Kms in the North-East of Aligarh Muslim University. They are a good source of water for their adjoining village. Farmers, commonly use the water of this wetland for irrigation of nearby small agricultural fields and also by washermen for washing clothes. They are also used for bathing and drinking water by cattles and other livestock. They are eutrophic water bodies with almost flat sloping basin having deep central area (Fig. A)

***Chharat wetland* 1 (CP-1)** covers an area of about.1.03 hect. and is normally 0.5 to 0.96 m deep. Both, area and depth, used to increase during monsoon months.

***Chharat wetland* 2 (CP-2)** covers an area of about 0.26 hect. with depth ranges between 0.52 to 0.96 m during different months of the study. The maximum depth was recorded in the months of July and August 2001 and the minimum during summer months when it dried up considerably due to high temperature. The main sources of its water supply are the monsoon rains, village drainage and surface run off from the adjoining areas.

Irregular and long shoreline is the characteristic feature of these wetlands. This triggers the productivity of these wetlands by increasing the opportunity of close ecosystem and superimposition of photosynthetic zone upon decomposition zone (Welch, 1952).

These wetlands contain dead planktonic organisms, organic and inorganic nutrients, wind blown materials and other suspended and dissolved materials. Bottom is muddy and composed of soil ranging from clay and silt to sand and gravel. Both the wetlands have suspended algal filaments as well as blooms of certain algal species on the surface in different seasons. The water is turbid, with luxuriant growth of plankton and mud at different times in different seasons (Table 5 and 12 - 14). A wide seasonal fluctuation in the water colour is noted throughout the course of study (Table 6).

Both the wetlands are rich in aquatic macrophytes, insects, fish, amphibians and other aquatic organisms. Amphibians are dominated by frogs and toads. Birds like *Ducks*, *Jal Murgi, Babulcus ibis*, *Giria,* *Nettapus* etc., are common inhabitants. Some water snakes, nematodes and worms are also commonly found in these wetlands during the course of study. Rest of the inhabitants have been discussed separately in Chapter V - ii.

Plate – 1: Medical Wetland (MP) with washermen's scrubbing slabs in view.

Plate – 2: Medical Wetland (MP) showing overhead Tank, one of the sources of replenishment

CP-1

CP-2

Plate - 3: CP-1 and CP-2 wetlands showing sampling sites.

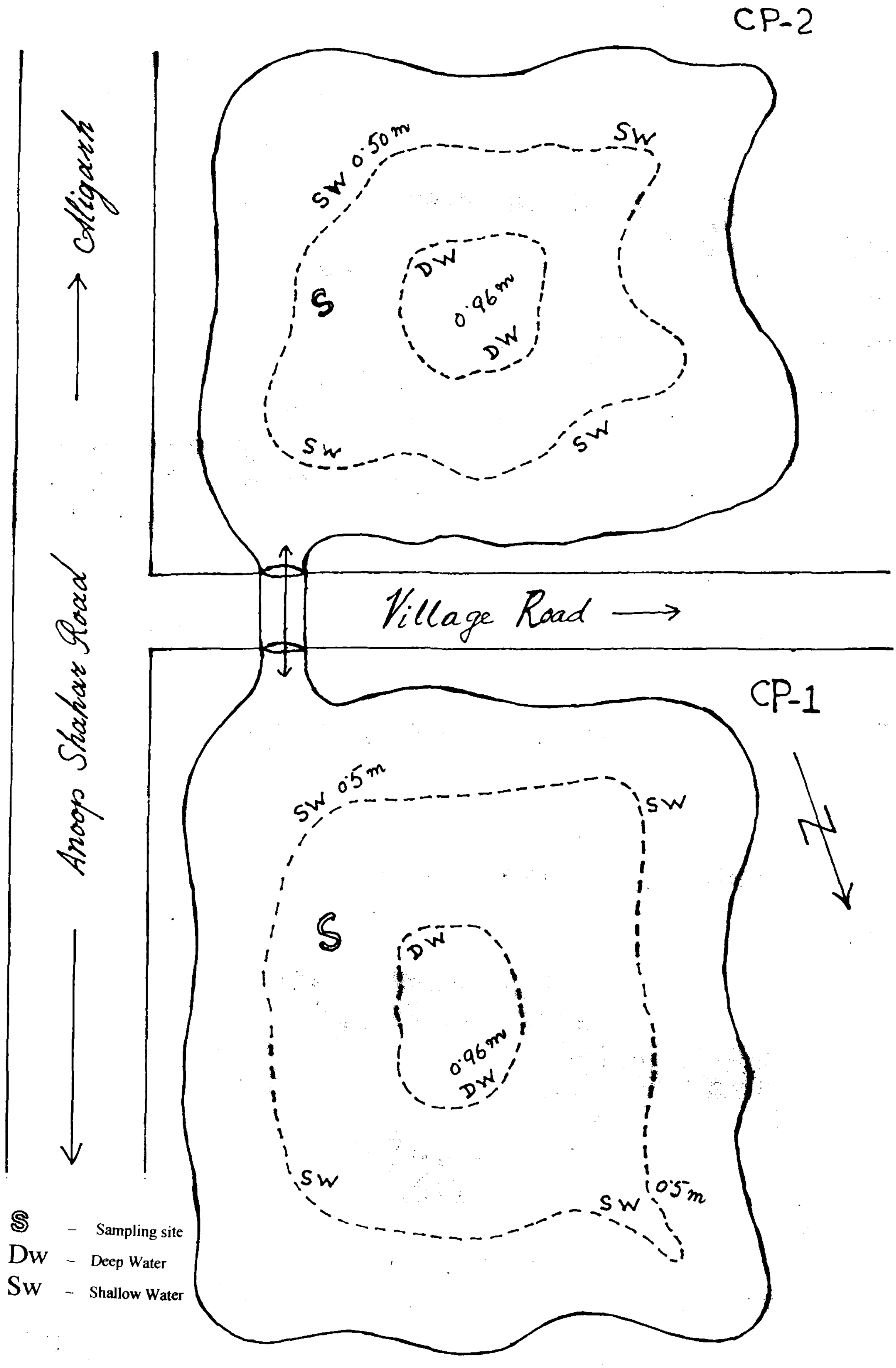

Fig. A - *Map of CP-1 and CP-2 Wetlands.*

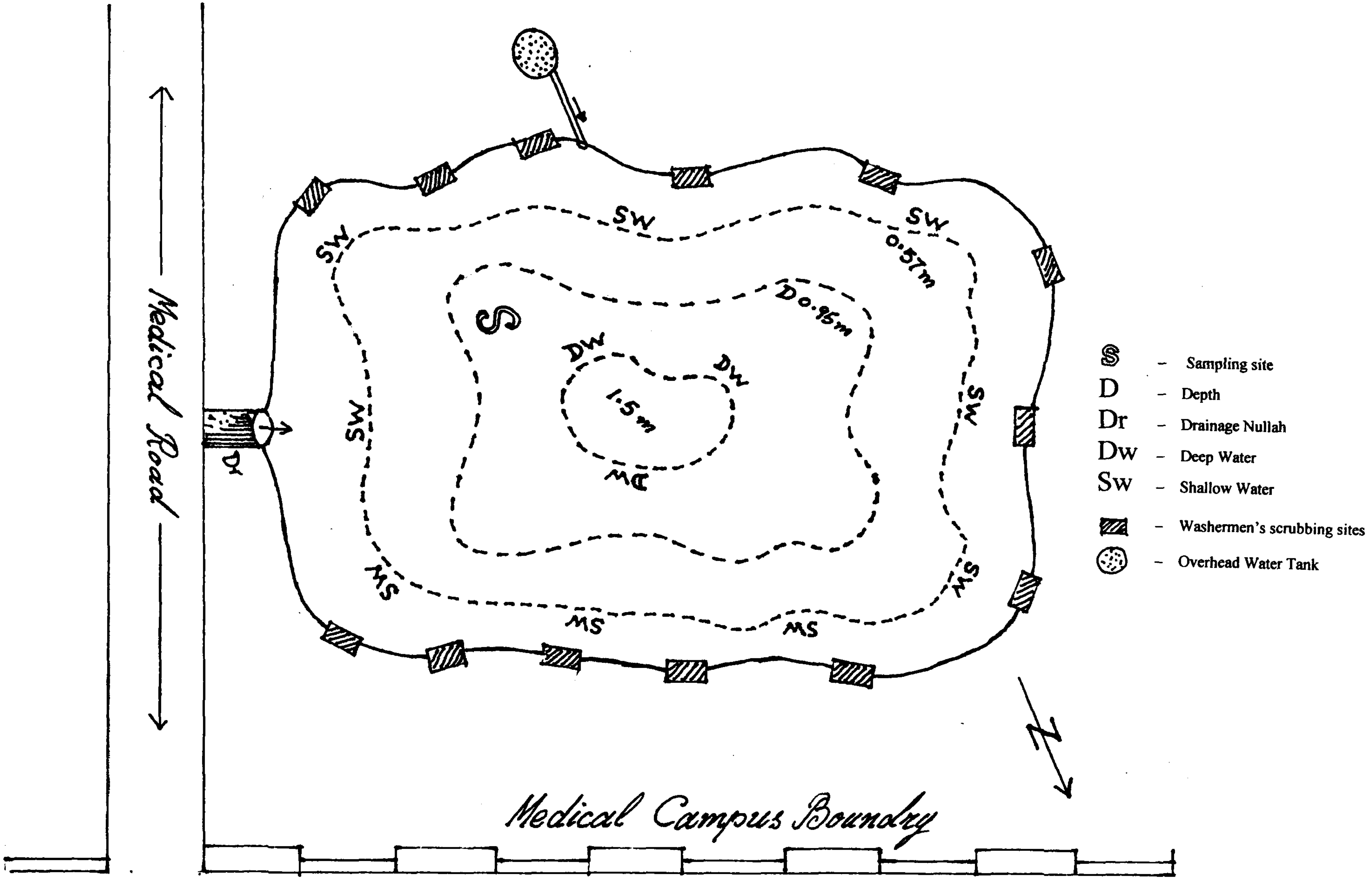

Fig. B - *Map of Medical Wetland.*

Chapter III

PHYSICAL LIMNOLOGY

(i) – CLIMATOLOGY OF ALIGARH REGION

Climatic factors like wind, rainfall, temperature, pressure and humidity play very important role in the ecology of aquatic as well as terrestrial environments (Barclay, 1966). Handa *et al.* (1987) and Panday and Tripathi (1988) have also reported the role of climatic factors in the ecology of aquatic environments. These factors control organic production in all the water bodies by affecting circulation and exchange of essential nutrients, (Rawson, 1951; Rodhe, 1958). For a scientific and sound approach to aquaculture practices, the understanding of climatic factors and their interactions with biological processes within the water body is also essential.

METHODOLOGY

The meteorological data of the study area are of considerable importance in the functioning of wetland ecosystem metabolism. Since the investigated wetlands are distributed within a radius of 3 to 8 kms, temporal variability of atmospheric temperature, rainfall, pressure, humidity, light intensity, wind velocity affect the systems seasonally rather spatially. The data were collected, for 17 months (August, 2000 to December, 2001), from Metrological Station of the Department of Physics, Aligarh Muslim University, Aligarh.

RESULTS

Quite different results are obtained during different seasons in atmospheric temperature, pressure, relative humidity, wind velocity, dew, and rainfall, as shown in the (Table 5a).

DISCUSSION

The North Indian wetlands represent a typical monsoon type of tropical climate. Aligarh, a district in Western Utter Pradesh in North India is characterised by seasonal rhythm marked by the north-east and south-west type of monsoons. The year can be broadly divided into following four seasons:

1. Winter season (December to February)
2. Summer season (March to June)
3. Monsoon season, i.e. season of general rains (July to September)
4. Post-monsoon season, i.e. season of retreating monsoon (October to November)

The **winter season** is marked with a gradual fall in temperature. Days are moderately warm but nights are cool. The region experiences a relatively good humidity and is mostly rainless. The winds during this season blow very slow, generally at an average speed of 4.29 km/hr.

The **summer season** is marked with a gradual shoot in temperature with bright sunshine and absence of cloudy days. The temperature shows a gradual increase in May, June and July. It is with lengthening photoperiod and a lower relative humidity. Hot dry winds of great velocity are a regular phenomenon during the season. The average wind velocity ranges between 4.80–12.80 km/hr during summer months. Though the monthly averages of the winds do not give a correct idea of the velocity and speed as they are liable to great variations during 24 hours. It blows with a force of gale during day, falls off very rapidly in the evenings and nearly calm down during nights. These fast winds are locally called as ***Loo.*** The occurrence of dust and thunderstorms caused by convection currents is a peculiar phenomenon of the hot weather season. There is no rains during the summer months except for the small amount accompanied by the thunderstorms. The wind velocity causes wave actions and strong currents and, as a result, fragmentation of filamentous algae and fragile organisms take place. *Microcystis* sp., a colonial form, produce smaller irregular and loosely constructed colonies due to wave actions .In wetlands, under investigations, it was found that during calm weather, *Diatoms*, *Copepods* and *Cladocerans* were abundant on the surface waters. Distribution of phytoplankton and so the concentration of chlorophyll also get affected in different layers of water by the action of wind (Small, 1963). Maximum concentration of chlorophyll was found in the surface water when the wind velocity was low. The wind produced waves and currents result in convective overturns (Lafond, 1962) and, as a result, the bottom water, richer in nutrients, rises and mixes with the surface water. This mixing brings in the essential nutrients into trophogenic zone. In this way, wind produced waves keep to ensure the nutrients in different layers of water for organic production (Lafond, 1962).

Summer season is followed by the **monsoon season**. During this season, rains start pouring. The rains generally begin in the middle of July and last till the end of September to early October. This season is characterised by a gradual fall in temperature, more numerous cloudy days, relative low light intensity, and gradual shortening of the photoperiod, high relative humidity and cyclonic weather. The months of July and August have steady rains (Table 5a).

Rains also affect the morphometry of wetlands. The maximum depth of the wetlands was recorded during the monsoon, thereafter gradual decline in the water level took place. The decrease in depth appears to be due to mainly evaporation and evapo-transpiration and partly due to seepage. Not only this, but the density of plankton gets affected by flooding of the wetlands during monsoon as the number of the plankton per litre of water decreases considerably, showing an inverse relationship with the intensity of rainfall. The extent of dilution of plankton is quite different in two wetlands. This seems to be due to morphometric differences. The relative volume of the water retained by these wetlands throughout the year was also different. Due to these factors the chemical and biological productivity in terms of nutrients and plankton, is quite different in *Chharat* and *Medical* wetlands. The month of May receives very little rainfall of 0.057mm while July and August are the months of most regular rains, the average for either months being 14.65mm and 13.17mm respectively. By the end of October there was a marked decrease in rainfall, 0.790mm (Table 5a).

The monsoon season is followed by a period of transition from rainy to dry and cool weather. This is the season of retreating monsoon and is termed as **post-monsoon season**. This season is characterised by a further fall in diurnal and nocturnal temperatures and a gradual decrease in photoperiods and relative humidity. The average rainfall in October was 0.790mm and the relative humidity in this month came down to 56.90% (Table 5a). As the sky clears and the sunshines, the day temperature rises while due to the dryness of the air there is a tremendous decrease in the night temperature.

Variations in air temperature are affected by the cold, dry and hot wind action during different seasons of the year. The **winter** is usually very cold whereas the summer is quite hot. The months of November, March and April are found to be moderate. The temperature changes in winter are influenced by the rainfall and cold winds, while the summer is influenced by the dry and hot winds.

Table 5a
Monthly Changes in Climatic Conditions at Aligarh

Parameters / Months	Temperature (°C)	Humidity (%)	Pressure (mm)	Dew Point (°C)	Rainfall (mm)	Wind velocity (km/hr)
August, 2000	30.00	83.24	1001.11	24.42	12.187	6.436
September	30.00	71.80	1004.40	22.82	10.490	4.827
October	29.00	59.80	1010.26	16.60	0.870	1.609
November	28.00	63.46	1017.30	11.53	0.158	1.609
December	22.00	69.46	1019.31	10.13	0.857	4.827
January, 2001	18.00	75.09	1017.12	9.40	0.052	3.218
February	20.00	64.98	1012.85	10.48	0.321	4.827
March	23.00	55.01	1009.60	12.90	1.450	4.827
April	25.00	34.78	010.66	15.66	0.042	6.436
May	33.00	32.70	1014.12	18.34	0.057	9.654
June	33.00	54.90	1002.10	22.67	1.830	12.872
July	32.00	82.01	1000.80	27.56	14.657	11.263
August	32.00	83.48	1000.40	25.64	13.176	9.654
September	32.00	70.71	1011.37	23.06	11.370	6.436
October	30.00	61.90	1018.49	18.41	0.790	3.218
November	20.00	64.82	1018.40	13.75	0.249	1.609
December	17.00	68.68	1017.11	11.35	0.746	3.218

(ii) – THERMAL REGIME OF THE WETLANDS

From the ecological point of view the thermal properties of water and corresponding relationships are the most important factors in maintaining fitness of the water in an ecosystem. The temperature of the surface waters governs, to a large extent, the biological species present and their rates of activity. A slight change in surface water temperature may affect the biology of the organisms present in that ecosystem (such as growth, development, reproduction and other life processes (Goldman and Horne, 1983; Wetzel, 1983). Knowing the temperature profile is important because the thermal regime of water directly affects the growth rate of all cultured species, development of density gradient in a water body and other water quality parameters, such as dissolved oxygen, pH and alkalinity (Boyd, 1990; Losordo and Piedrahita, 1991). The distribution of gases and nutrient cycle along with other biogenic processes get affected by the changes in the temperature of the environment (Welch, 1952). It also governs the water mixing, turbulence and production of currents (Ruttner, 1963; Cole, 1983).

Solar radiation is the main source of heat to any aquatic ecosystem and the energy that distributes heat in the environment is derived from wind (Birge, 1916). The temperature of natural water systems responds to many factors, the ambient atmospheric temperature being the most universal. Generally shallow waterbodies are more affected by ambient air temperature than are deeper water bodies (Efford, 1967; Moss, 1969). Heat is taken up directly through direct absorption by water and through the transfer of heat from the air or from the bottom in the water body. The source of incoming water and nature of drainage pattern also determine the thermal properties of the water (Reid, 1961). Transport of heat is most effective in the ponds, as the temperature differences between surface and bottom are not found to be great (Ruttner, 1963). Fishers and Fabris (1982), Imber *et al.* (1985) and Zhou and Wangersky (1985 and 1989) have reported that algal physiology is highly dependent on the temperature, salinity and light.

Waterbodies frequently undergo diel cycles of thermal and chemical vertical stratification and destratification under hot and quiescent weather conditions

(Cathartic and Wheaton, 1987; Boyd, 1990; Szyper and Lin, 1990; Losordo and Piedrahita, 1991). Heat transfer by turbulent diffusion regulates the fish movement along with the plankton distribution (Zhu *et al.*, 2000).

Large amount of work has been done on the thermal properties of fresh water ecosystem. In addition to above mentioned works, some important contributions from India and abroad are those of Ganapati (1960), Sastry and Mryland (1960), Singh (1960), Conover (1961), Reid (1961), Smith (1962), McLaran (1963), Gorhan (1964), Johnson (1965), Phinney and McIntire (1965), Zafar (1966), Munawar and Zafar (1967), Anderson (1968), Brock and Brock (1968), Ramamirthan (1968), Vijayraghavan (1969), Ganapati and Sreernivasan (1970), Schindler (1971), Epply (1972), Larson (1972), Rangarajan and Marichany (1972), Gachter *et al.* (1974), Peelen (1974), Vasisht and Sharma (1975), Sweeney (1976), Bohra *et al.* (1978), Qadri and Yousuf (1978), Yousuf *et al.* (1984), Fadal *et al.* (1987), Bomber *et al.* (1988), Webb and Parsons (1988). Khan *et al.*(2000), Zhu *et al.* (2000) and Gaur *et al.* (2001),

METHODOLOGY

Atmospheric and surface water temperatures were recorded by a mercury thermometer graduated up to 100°C between 9-10 A.M. at regular intervals during August, 2000 to December, 2001.The surface water temperature was measured by immersing the thermometer's mercury bulb into the water for about 2-3 minutes following a procedure and precautions given by Welch (1948).

RESULTS

Monthly surface water and air temperature in CP-1 , CP-2 and MP, wetlands have been given in Table 5 and illustrated in Fig. 1. Apparent seasonal and monthly changes were found in both air and water temperatures. The water temperature was found to be closely related to the air temperature.

The air temperature varies from 17 to 33°C at CP-1; 17 to 34 °C at CP-2 and 15 to 36°C at MP wetlands. The water temperature of the surface water also showed wide variations from 15 to 31°C at CP-1; 16 to 32 °C at CP-2 and 14 to 32 °C at MP (Table 5 and Fig. 1).

In all the three wetlands, the high surface temperature was recorded during summer as the water gets rapidly heated during the day time having long photoperiods and clear sky. It was also recorded high during monsoon months because of high humidity and higher temperature.

The lower water temperature was recorded during the winter months, as the warm effect of the solar radiation over this period was low in all the three wetlands that brings drop in water temperature.

Since the investigated wetlands are distributed within a radius of 8 kms, seasonal variability of atmospheric temperature would affect the system temporally rather spatially.

DISCUSSION

Temperature fluctuation in these wetlands was the result of addition or loss of heat. The heating and cooling greatly depends upon air temperature regulated by relative humidity, solar radiation, photoperiods, and cloud cover etc. However, the assessment of all meteorology parameters have affected the atmospheric temperature, which is essential in determining the energy budget of a wetland. In the present study too, these wetlands being small in size and shallow eutrophic water bodies, get quickly changed with the ambient conditions and thus show wide fluctuation. The surface area, and volume of the wetlands are extremely important to assess fluctuation of temperature (Anderson, 1964). Most of the months show more fluctuation in air temperature than in the surface water temperature (Table 5).

Thermal regime of these wetlands appears to be related to the morphometry. As they are shallow, fluctuations in temperature results in convection currents, which lead to complete turn over (Ruttner, 1963). The complete mixing of water is regulated by the thermal changes along with the wind action, which agitate the water and the heat is transported quickly to various depths in these shallow wetlands. Such mixing of water is not possible in deeper lakes and deeper central basin of lakes while complete mixing occurs in shallow margins of the lake (Anderson, 1968). In all the three wetlands, under study, homogeneity of temperature at different levels was observed and no thermal stratification was noted. Berst and Mc Crimmon (1966) have also reported no thermal stratification in similar water bodies. The frequent mixing of water in these wetlands ensures the better aeration at depths and continuous replenishment of the upper water layers with nutrients, which increases the productivity of wetlands (Reid, 1961).

The pattern of seasonal fluctuations in air and water temperatures broadly agrees with the solar radiation and the photoperiods of the seasons. Surface water temperature is closely reflected to ambient air temperature (Efford, 1967 and Moss, 1969). A cold, dry and hot wind wave brings variations in air temperature in different seasons. The winter being usually cold whereas summer quite hot. The months of April and November are found to be moderate. Physico-chemical and biological properties are also triggered with the changes in air temperature.

Statistical analysis shows a very significant positive correlation between monthly air and water temperatures (Table19 and Fig. 12).

Temperature also plays an important role in dynamics and biology of plankton organisms. In this study, maximum densities of various planktonic groups were usually observed during post-monsoons and winter seasons when the temperature was most suitable for their growth and reproduction. (Tables 5 and 12 to 17). But it is difficult to pinpoint the effect of temperature on the plankton, as a whole, because the response of the various groups and species to different temperature regimes is different.

Table 5

Monthly variations in Air and Surface Water Temperatures (°C), Transparency (cm) and Turbidity (% t) in Wetlands.

Months ↓	Air Temperature			Water Temperature			Transparency			Turbidity		
Wetlands →	**CP-1**	**CP-2**	**MP**	**CP-1**	**CP-2**	**MP**	**CP-1**	**CP-2**	**MP**	**CP-1**	**CP-2**	**MP**
August, 2000	30.0	30.0	32.0	29.0	29.0	30.0	17.3	15.2	15.2	62.0	60.0	73.0
September	30.0	29.0	30.0	28.0	28.0	28.0	17.2	14.7	17.2	69.0	50.0	75.0
October	29.0	29.0	28.0	28.0	28.0	26.0	18.3	17.2	21.1	72.0	64.0	54.0
November	28.0	29.0	28.0	27.0	27.0	25.0	16.3	15.0	33.2	60.0	32.0	86.0
December	22.0	21.0	19.0	21.5	20.0	18.0	28.2	26.5	28.2	94.0	83.0	64.0
January, 2001	18.0	17.0	15.0	17.0	16.5	14.0	28.3	27.2	13.1	80.0	82.0	24.0
February	20.0	20.0	18.0	19.0	19.0	17.0	38.5	26.2	13.5	97.0	82.0	26.0
March	23.0	23.0	21.5	21.5	21.0	20.0	35.4	36.2	15.5	92.0	89.0	22.0
April	25.0	25.5	23.0	23.0	29.0	22.0	26.5	27.0	14.2	71.0	69.0	17.0
May	33.0	34.0	26.0	29.0	30.0	23.0	13.5	18.1	26.5	27.0	29.0	33.0
June	33.0	34.0	32.0	30.0	32.0	30.0	9.1	12.5	32.2	24.0	28.0	58.0
July	32.0	32.0	36.0	30.0	31.0	32.0	14.5	16.1	35.3	33.0	33.0	66.0
August	32.0	34.0	31.0	31.0	32.0	32.0	13.1	24.4	36.5	43.0	39.0	74.0
September	32.0	33.0	22.0	30.0	31.0	30.0	22.5	25.7	38.1	70.0	88.0	76.0
October	30.0	28.0	32.0	28.0	27.0	25.0	25.3	21.2	29.5	70.0	74.0	55.0
November	20.0	22.0	19.0	17.0	19.0	18.0	25.5	29.5	34.5	87.0	86.0	87.0
December	17.0	20.0	19.0	15.0	16.0	18.5	30.5	35.5	17.5	85.0	94.0	41.0

CP-1: Chharat Pond 1; CP-2: Chharat Pond 2; MP: Medical Pond

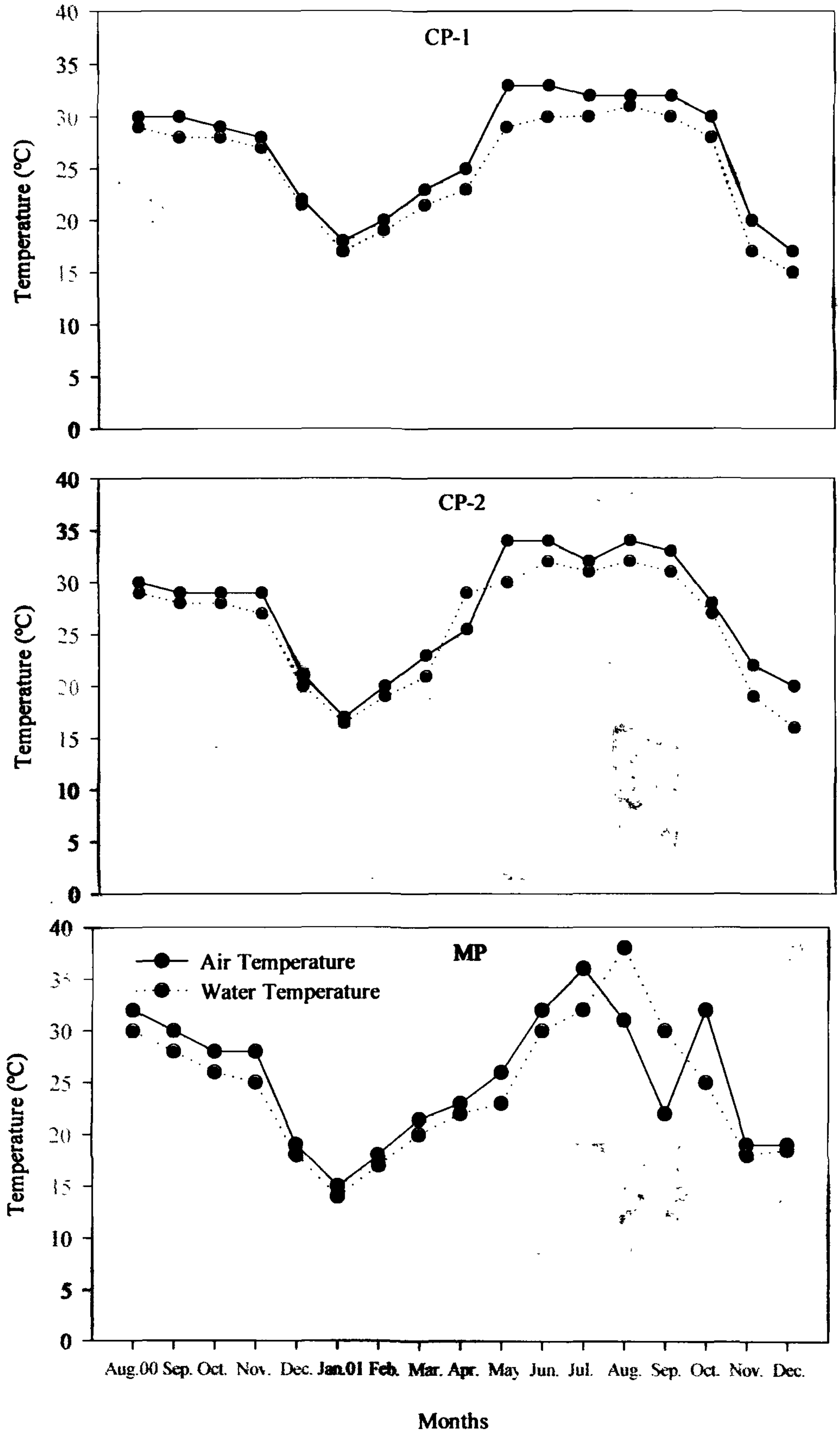

Fig. 1. Monthly variations in Air and Water Temperature (°C) at CP-1, CP-2 and MP Wetlands.

(iii) – LIGHT CONDITIONS IN THE WETLANDS

Light is important to aquatic animals as well as to plants, and a voluminous literature exists on their relationships (Cole, 1983). The arrival of solar radiation at the surface marks the beginning of the photochemical and other biological reactions of flora and fauna in a water body. Except for well-known uranium fission and hydrogen fusion devices, one is hard pressed to list energy sources that do not depend on the sun (Cole 1983). Perhaps the earth's internal heat and moon-pulled tides are the only other non-solar sources of energy we can list. Thus, it becomes a subject of interest for a limnologist to know:

i) How much radiation falls on the surface of a water body within a span of time,

ii) How far it penetrates, and

iii) How it can be used or how it affects the aquatic organisms.

Radiant energy is transformed into potential energy by biochemical reactions, during photosynthesis of aquatic plants or to heat and thus control the productivity of the water body. It also controls various metabolic activities of aquatic flora and fauna (Wetzel, 1983). Natural waters exhibit great differences in the degree, to which sunlight can illuminate them and wide seasonal and diurnal fluctuations are noted (Hutchinson, 1957). Certain physico-chemical properties are responsible for the amount of light energy absorbed by water, such as intensity of light at surface, differences in latitude, molecular structure of the water itself, suspended particles and dissolved inorganic and organic compounds (Wetzel and Likens, 1979). Light absorption by suspended particles is an important characteristic of aquatic ecosystem because it greatly determines their optical properties and it reflects the nature of these particles (Kirk, 1986). In particular, light absorption by phytoplankton is an important component of planktonic primary production (Maara *et al.,* 1993), but it is not necessarily the dominant source of light absorption particles.

Despite the large amount of literature exists on the light conditions, photosynthesis, turbidity, transparency of aquatic ecosystems, there is a dearth of information relating to light. Birge and Juday (1929), Atkins (1932), Chandler (1944), Jerlov (1951), Beeton (1958), Strickland (1958), Stephens and Strickland (1962), Rodhe (1965), Talling (1965), Tandon and Singh (1972), Hutchinson (1957), Spence (1976), Khan *et al.* (1978), Thompson *et al.* (1979), Wetzel and Likens, (1979), Champ *et al.* (1980), Lorenzen (1980), Cole (1983), Datta *et al.* (1983), Kirk (1986), Wetzel (1983) , Chambers and Kalff (1985) Pennock (1985), Pierce *et al.* (1986), Carter and Rybicki (1985) and Maara *et al.* (1993) have given interesting and useful detailed accounts on the principles of light penetration in different types of water bodies, its measurements and effect on aquatic organisms. Besides this, other workers have also reported their findings regarding photosynthesis and light in an aquatic ecosystem. Information on light attenuation in turbid fresh to brackish and coastal environments comes mostly from researches on phytoplankton dynamics and water quality (Thompson *et al.*, 1979; Champ *et al.*, 1980; Pennock, 1985 and Pierce *et al.*, 1986). Others reported that light availability and irradiance limit submersed macrophytes growth and photosynthesis in fresh and saline waters (Spence, 1976; Phillips *et al.*, 1978; Dennison and Alberte, 1982, 1985, 1986; Chambers and Kalff, 1985 ; Kirk, 1983 ; Dennison, 1987). The spatial composition of light has also been suggested as a factor controlling the depth distribution of submerged macrophytes (Buesa, 1975; Kirk, 1979 and 1983; Chambers and Prepas, 1988). In many parts of the world, progressive nutrient enrichment has led to the disappearance of macrophyte population (Jupp and Spence, 1977; Phillips *et al.*, 1978; Moss, 1979 and 1983). Kemp *et al.* (1983) have suggested that light attenuation by suspended sediments and epiphytes loading caused by increasing nutrient levels may be implicated in the decline of submerged macrophytes in Chesapeake Bay.

METHODOLOGY

Transparency, *the limit up to which light can penetrate in a water body,* was determined by using standard Secchi disc method. A weight Secchi disc, having diameter of 30 cm and divided into black and white quadrants at surface, is lowered into the water body. The average of the two depth readings at which Secchi disc disappeared and reappeared, was noted as transparency.

Turbidity, *a measurement of the extent to which light is either absorbed or scattered by suspended matters in the water,* was directly determined by *Spectronic*-20 spectrophotometer (*Bausch and Lomb*) at a wavelength of 660 nm in terms of percent transmission. Further, extinction coefficient was also determined from the Secchi disc reading using formula.

E.C. = 1.7/D;

Where 'D' is the maximum depth at which the disc was visible, and 1.7 is the factor (Khan, 1969).

RESULTS

Values of **Transparency** and **Turbidity** of the three wetlands, under investigations, are given in the Tables 5 and shown in Fig. 2. In CP-1, **Secchi disc transparency** ranged from 9.1 to 38.5 cm, the maximum was noted in the month of February 2001, and minimum in the month of June 2001 (Table 5). CP-2 showed a range of 12.5 to 36.2 cm, with maximum value recorded in the month of March, 2001 and minimum in the month of June, 2001. Similarly, in MP, maximum value of 38.1 cm was noted in the month of September, 2001 and minimum of 14.2 cm was found in the month of April, 2001.

Transparency values in wetlands, CP-1 and CP-2 were found to be higher in the winter and post-winter months, while in MP wetland, it was higher in the post-monsoon, summer and monsoon months (Table 5 and Fig. 2).

The **turbidity,** which is caused mainly by micro-organisms, dissolved and suspended organic and inorganic matters in the water medium, showed wide seasonal fluctuations (Table 5 and Fig. 2). In CP-1, turbidity varied from 24 to 97% transmission in the months of June, 2001 and February, 2001 respectively. Similarly in CP-2, turbidity values varied from 28 to 94 % transmission in June, 2001 and December, 2001 respectively. In the case of MP pond, turbidity showed variations from 17 to 87 % transmission in the months of April and November, 2001 respectively. From these observations it can be assessed that turbidity was higher in the summer and monsoon months and lower during rest of the months in CP-1 and

CP-2 wetlands (Table 5), while in the case of MP wetland, turbidity was found to be higher during winter and post-winter months and lower during rest of the studied period. Values obtained for E.C. varied from 0.044 to 0.173; 0.047 to 0.136 and 0.044 to 0.129 at CP-1, CP-2 and MP (Table 7).

DISCUSSION

The values of transparency showed wide seasonal fluctuations (Table 5 & Fig 2). Transparency in CP-1 and CP-2 was found to be higher in winter and post-winter months and lower during summer and monsoon months, whereas in MP the maximum values were obtained during summer, monsoon, post-monsoon months and minimum during winter and post-winter months. The transparency of these wetlands depends upon the turbidity of waters (Chandler, 1944 and Hutchinson, 1957), which is mainly caused by silt, clay, micro- organisms, suspended organic and inorganic matter in these wetlands.

Turbidity was found to be lower during winter and post-winter months both at CP-1 and CP-2 and higher during summer and monsoon. In MP it was higher during winter and post-winter and low during summer, monsoon and post-monsoon. All these wetlands receive sewage from surrounding residential areas along with stains and other washing chemicals, dirt, and other impurities from washermen's activities (only at MP). Similar reasons have been given by (Haque, 1991) who studied a similar type of pond. A significant positive correlation between transparency and turbidity (Table 19 and Fig. 13) was found to exist in these wetland ecosystems (at CP-1; $r = 0.891$, $p < 0.05$, CP-2; $r = 0.809$, $p< 0.05$, and at MP; $r = 0.692$, $p < 0.05$). The species richness of submerged macrophytes appeared to be highest under transparent conditions as also reported by Jackson and Charles (1988) and Rorslelt (1991). Transparency conditions are important in ensuring a wide vertical extension of the macrophyte zone along a depth gradient of changing physical exposure, sediment composition and light intensity, allowing many species of different adaptation and life strategy to participate in the zonation (Spence, 1982).

All the three wetlands consist of inorganic solids as clay, silt and other soil constituents. Also plant fibres, biological solids (algal cells, bacteria, dead and decay leaves) and wind impurities etc. constitute the suspended solids. These materials are often regarded as natural contaminants resulting from erosive action of water flowing in these wetlands. Other organic and inorganic suspended materials are also added due to human activities in the form of domestic wastes. In the case of MP, it is due to washermen's activities. Like suspended materials, dissolved substances are also important. Metals and minerals, which are soluble in water act as dissolved solids. There is a good interaction of water of wetlands with such dissolved chemicals. Decayed and decomposed materials of vegetation also formed the dissolved constituents in these wetlands.

Statistical correlation analyses were made to determine the relative effect of turbidity, transparency, T.S., T.D.S., T.S.S., phytoplankton and zooplankton on the extinction of light using seventeen months average observations of the above-mentioned parameters (Table 19). Significant inverse relationship was obtained between transparency and T.S, T.S.S. and T.D.S. (Table 19).

It was found as usual that high transparency values were associated with less turbid values (Table 5) and (Figs. 2 and 13), whereas low transparency values were found with high turbidity in the waters of these wetlands. In the case of CP-1 and CP-2, water was found to be highly turbid during summer and monsoon. It was mainly due to occasional rains and incoming silt and clay along with the surface run-off from the catchment areas, whereas in the case of MP, higher turbidity was noted during winter and post-winter months. It was mainly due to suspended as well as dissolved organic and inorganic substances including chemicals and stains added by the washermen. The suspended silt and organic detritus settled and, consequently, the turbidity decreases resulting in the increase of transparency to its maximum value in September, 2001. Since the turbidity values were recorded in terms of percent (%) transmission, a significant direct relationship was found between the transparency and turbidity (Table 19).

Plankton and other organic and inorganic particles reduce transparency in all these wetlands. There lies a great importance of plankton and transparency of these wetlands (Table 19). The relative importance of the phytoplankton on the transparency of water was also investigated. It can be seen from the Table 19, that during most of the times high values of transparency coincide with the low phytoplankton population, but in the present study, statistically, it does not represent significant relationship (CP-1, $r = -0.111$, $p < 0.05$; CP-2, $r = 0.239$, $P < 0.05$; MP, $r = -0.350$, $P < 0.05$).

All these wetlands, like other ponds and lakes, are usually low in transparency. It is because of high turbidity affected by inflow of sewage effluents, chemicals, detergents and stains (only at MP) throughout the course of study. Further, transparency was also low due to the dense population of plankton during winter and pre-monsoon months (Table 5 and 12-17).

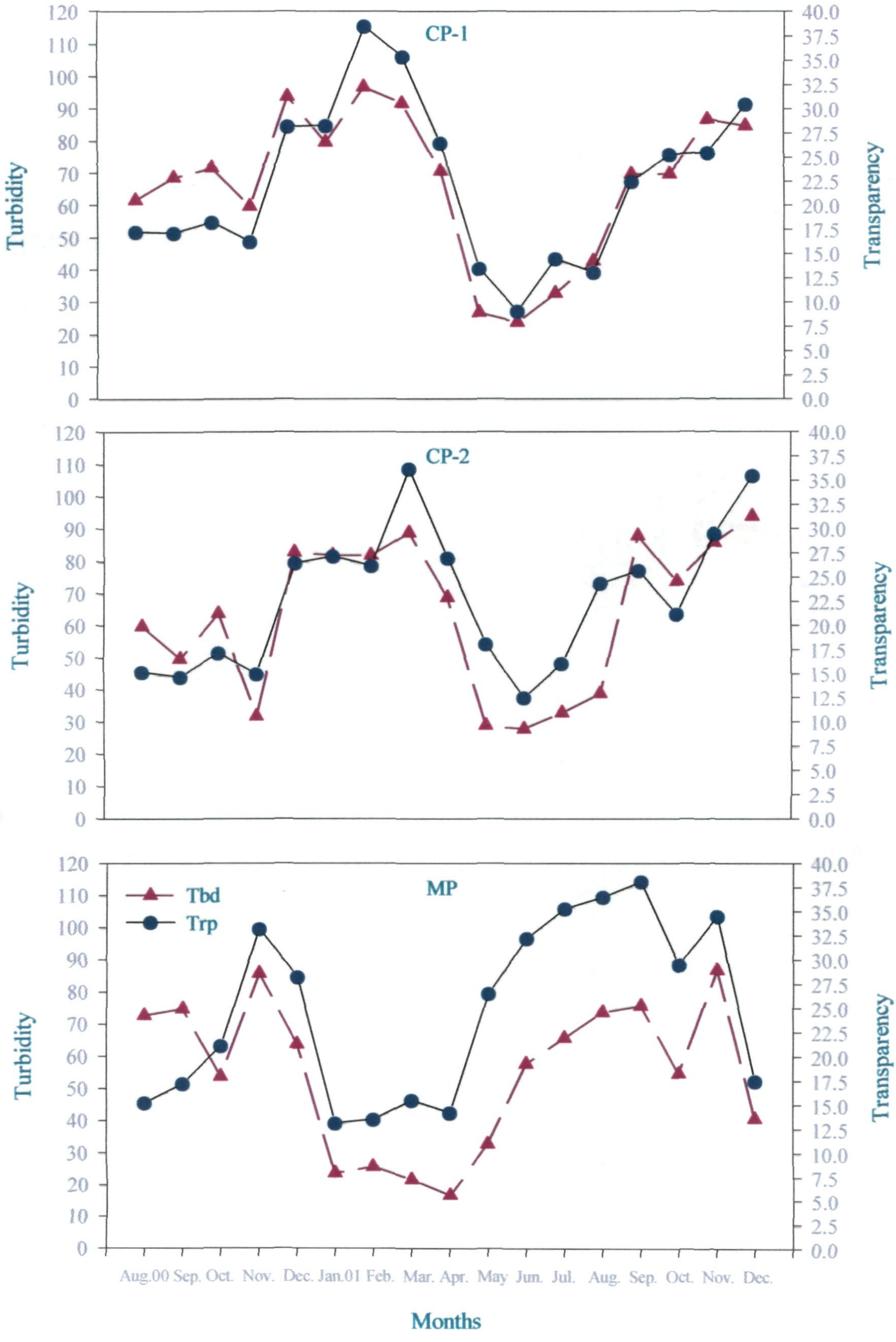

Fig. 2. Monthly variations in Turbidity (% t) and Transparency (cm) at CP-1, CP-2 and MP Wetlands.

Chapter IV

CHEMICAL LIMNOLOGY

(i) – OXYGEN REGIME IN THE WETLANDS

Natural water bodies load a great variety of gases dissolved in them. Out of these gases, oxygen is the most significant one as it is a regulator of metabolic processes in the organisms (Kaushik and Saksena, 1999). It directly affects the survival and distribution of flora and fauna in an ecosystem (Vijaykumar *et al.*, 1999). Dissolved oxygen (D.O.) is a fundamental requirement for the maintenance of balanced indigenous populations of fish and other aquatic biota. Despite the fact that all of us are taking oxygen into our bodies and converting it into carbon dioxide as part of a metabolic process to extract energy from our food, the amount of oxygen in the atmosphere remains remarkably stable at about 20.95% of the air (Wetzel, 1983).

Some aquatic animals and plants have specific ways of getting oxygen directly from the air, but most remove oxygen dissolved in the water. Because oxygen dissolved in water is far less abundant than oxygen present in the air, the actual amount of dissolved oxygen present is an important water quality parameter. As a general rule, the more oxygen dissolved in water will support more numbers and variety of aquatic organisms. There is a limit to how much oxygen water can hold before it is saturated. This amount is called the oxygen solubility or saturation value, which is not fixed, but depends upon *oxygen pressure in the air, water temperature, dissolved salts* present, *wave action, pollution, inflowing underground water, photosynthetic activity* of plants and *respiration* by *bacteria, plants* and *animals* in the water etc. (Zutshi and Vass, 1978). The range of D.O. is quite great in small wetlands (Kaushik and Saksena, 1999). In Indian waters, Singhal *et al.* (1986), Valencha and Bhatnagar, (1988), Yousuf and Mustafa (1988), Kant and Raina (1990), Shastree *et al.* (1991) and Kaushik *et al.* (1991a, b) have reported great D.O. variations in different water bodies or even in the same water body at different places.

A great deal of literature exists on the oxygen regime of aquatic ecosystems, both from temperate and tropical waters. Some important contributions include the works of Hutchinson (1957, 1975), Sreenivasan (1964, 1965 and 1972), Ramamirthan (1968), Michael (1969), Khan and Siddiqui (1971), Jana and Sarkar (1971), Tandon and Singh (1972), Khan *et al.* (1978), Unni (1982), Datta *et al.* (1983 and 1984), Singhal *et al.* (1986), Yousuf *et al.* (1986), Bernice *et al.* (1987), Kulshreshtha *et al.*

(1987), Haque *et al.* (1988), Shastree *et al* (1991), Carter and Rybicki (1991), Vijaykumar (1992 and 1999), Dhamija and Jain (1994, 1995), Mukherjee *et al.* (1994). Kumar (1995, 2002a), Rao and Mahmood (1995), Birsal (1996), Lowell and Culp (1999), Dayananda *et al.* (2002), Khan *et al.* (2002), Hosetti (2002) and Verma and Sharma (2002).

METHODOLOGY

Collection of water sample for the study of dissolved oxygen (D.O.) was done from the surface for a period of 17 months from August 2000 to December 2001 from three wetlands of Aligarh region, namely CP-1, CP-2, and MP.

Analysis of the samples for D.O. determination was made on the site of collection following Winkler's modified technique (APHA, 1992). Duplicate samples were taken for each analysis.

RESULTS

In CP-1, monthly dissolved oxygen contents of surface waters varied from 4.0 to 9.6 mg/L, while in CP-2 it varied from 4.2 to 11.6 mg/L in the surface waters. In MP, it varied from 4.2 to 9.4 mg/L (Table 6). The maximum concentrations of D.O. in CP- 1 and CP-2 were recorded in June, 2001, while in MP during March, 2001. The minimum concentration was noted during February 2001, in CP-1 and CP-2, whereas in case of M.P. minimum concentration was noted in the months of September, 2000 and August, 2001 (Table 6).

In the present investigations, wide fluctuations of D.O. have been noted throughout the course of study (Table 6 and Fig.3). In CP-1, higher values of D.O. were recorded in monsoon months of 2000 (August and September) and summer months of 2001 (May-June), and low in the post- winter months (February and March) and post- monsoon months (October and November) of 2001 (Table 6). In CP-2, higher values of D.O. were observed in the monsoon months of 2000, summer months (April to June) and post monsoon month (September) of 2001, and low concentrations were recorded in the winter months December, 2000 to March, 2001 and during October, 2001 (Table 6).

In the case of MP, higher values of D.O. were recorded in the months of (March, November, and December, 2001) and low values during rest of the studied period (Table 6).

DISCUSSION

Higher values during monsoon months (CP-1) and in some summer months (CP-1 and CP-2) were mainly due to agitation of water caused by the falling of rain water as well as by the dilution of pollutants at the same time. Also high rate of photosynthetic activity triggers the maximum D.O. regime of these wetlands during summer months with increased population of phytoplankton. The light intensity was also found to be quite favourable during summer months for photosynthesis. The similar observations have been reported by Qadri and Yousuf (1978), Bisht and Das (1985), Ayyappan and Gupta (1981). Bhatt and Negi (1985), Shukla and Bais (1990) and Vijaykumar (1992), who reported higher values during summer months, and they attributed this to increased solar radiation and considerable good standing crop of phytoplankton. Low values of D.O. during winter months at CP-2, Post-winter months at CP-1, post-monsoon months at CP-1and MP and monsoon months at MP were found to be due to several factors acting at different time, like low photosynthetic rate during monsoon months (Yousuf and Mustafa, 1988), inflowing drainage water containing varying amount of pollutants during different months (Trivedy, 1988), respiration by bacteria, plants and animals (Kaushik and Saksena 1999), dilution of water during monsoon months and other organic pollutants which enter into the water body along with the surface run-off during rainy season and causes depletion of D.O. during decomposition process (Trivedy, 1988).

Similarly, in MP, the higher concentrations of D.O., found during March, 2001 and during winter months, may be attributed to increased solar radiations (March) which help in increasing photosynthetic process and lowering of water temperature (November and December) with increased phytoplankton density. Mishra *et al.* (1997) have also reported similar observations. The low D.O. concentration in the monsoon months was possibly due to incoming drainage and surface run-off water containing very low or no D.O. and low photosynthesis during the period. Similar results were also reported by Munawar (1970), Swarup and Singh (1979), Qadri and Mustafa (1984), Yousuf *et al.* (1986) and Yousuf and Mustafa (1988).

The D.O. content has also been reported to be significantly associated with transparency, temperature and free CO_2 content (Mishra *et al.*, 1997). Ray *et al.* (1966) have reported an inverse relationship between D.O. and water temperature. Statistically, in the present study too, relationship between water temperature and D.O. (Fig. 14) was found to be positive at CP-1 ($r = 0.453$, $p<0.05$) and at CP-2 ($r = 0.601$, $p < 0.05$) but negative at MP ($r = -0.656$, $p<0.05$). In all these wetlands surface changes in D.O. were found to be directly related with the changes in phytoplankton density (Table 6). A positive correlation was found between these two variables in CP-1 and MP wetlands and negative at CP-2. This emphasizes the significance of producer communities in the aeration of shallow water bodies (Reid, 1961 and Hutchinson, 1975).

Tarzwell (1957) has suggested that a minimum of 3.0 mg/L D.O. is necessary for healthy fish life, but George (1961) has maintained that concentration of 1.4mg/L oxygen is sufficient to maintain life in water. Das (2000) has observed that D.O. concentration of more than 5.0 mg/L favours good growth of flora and fauna. In the present investigations, the average value of D.O. was never found below 4.0 mg/L (Table 6) indicating that the studied wetlands can be very well utilized for aquaculture activities.

Table 6
Monthly variations in Dissolved oxygen (mg/L), pH and Water Colour in Wetlands.

Months ↓	Dissolved Oxygen (D.O.)			pH			Water Colour		
Wetlands →	CP-1	CP-2	MP	CP-1	CP-2	MP	CP-1	CP-2	MP
August, 2000	8.0	9.2	6.2	8.4	8.6	9.2	Greenish	Greenish	Greyish
September	9.3	9.7	4.2	8.4	8.6	9.1	Greenish	Greenish	Greyish
October	6.4	6.0	4.8	8.4	8.6	8.8	Greyish	Greyish	Greenish
November	6.2	6.0	5.4	8.4	8.4	8.8	Greenish	Greenish	Greyish
December	6.4	4.4	6.2	8.5	8.4	8.9	Greenish	Greenish	Greenish
January, 2001	6.9	5.2	6.4	9.1	9.0	8.8	Greyish	Greyish	Greyish
February	4.0	4.2	6.2	9.0	8.9	8.7	Greyish	Greyish	Greyish
March	5.0	4.8	9.4	8.7	8.6	8.4	Greyish	Greyish	Greenish
April	6.4	8.0	5.0	8.7	8.8	8.7	Greyish	Greyish	Greenish
May	8.0	8.2	5.6	9.2	8.9	8.6	Greyish	Greyish	Greenish
June	9.6	11.6	5.0	9.1	9.1	8.7	Greyish	Greyish	Greyish
July	7.0	6.8	4.4	9.1	9.1	8.9	Greyish	Greyish	Greyish
August	6.8	7.0	4.2	9.1	9.1	8.3	Greyish	Greyish	Greyish
September	8.8	9.0	5.2	8.4	8.5	9.3	Greenish	Greenish	Greenish
October	4.4	4.6	6.4	8.4	8.5	9.1	Greyish	Greyish	Greyish
November	6.0	6.0	8.0	8.4	8.4	8.8	Greyish	Greenish	Greyish
December	7.0	7.6	8.2	8.6	8.8	8.6	Greyish	Greyish	Greyish

CP-1: Chharat Pond 1; CP-2: Chharat Pond 2; MP: Medical Pond

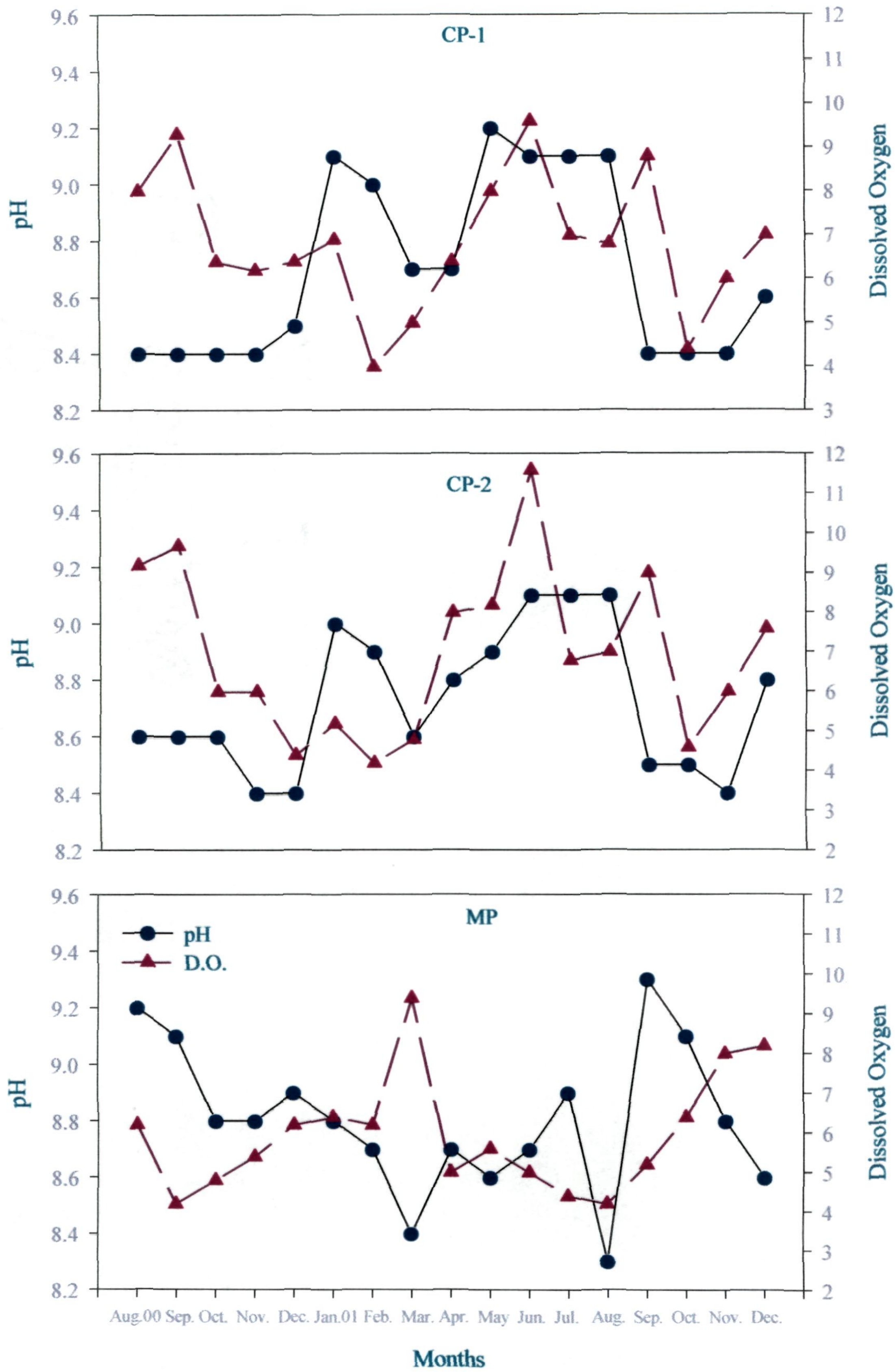

Fig. 3. Monthly variations in pH and Dissolved oxygen (mg/L) at CP-1, CP-2 and MP Wetlands.

(ii) – CARBON DIOXIDE SYSTEM IN THE WETLANDS

One of the important substances in the life of the plants and micro-organisms is carbon dioxide. Its presence gives an opportunity to green macro-and microphytes including phyto-plankton to synthesise their food and produce oxygen, which is basic need of all animals and plants. On the other hand, large amount of CO_2 in the ecosystem is harmful to life. The carbon dioxide in aquatic ecosystems is found in two forms, in free state (gas form) and in combination with other substances.

The free $\mathbf{CO_2}$ contributes to the fitness of natural waters as it serves to buffer the environment against rapid changes in the pH and also regulates biological processes in aquatic communities to form many compounds. There are many sources of CO_2 in a water body. They include atmospheres CO_2, respiration by the organisms and bacterial decomposition of organic matter etc (Kaushik and Saksena, 1999). The presence or absence of free CO_2 in the surface water is mostly governed by its utilization by algae during photosynthesis and also through its diffusion from air (Sreenivasan, 1974). Thus free CO_2 may be present throughout the year (Ganapati 1956; Verma, 1969; Sreenivasan, 1972; Chourasia and Adoni, 1985 and Singhal *et al.*, 1986) or in some samples taken in few successive months of a year (Verma and Shukla, 1968; Qadri and Yousuf, 1978; Kaushik *et al.*, 1989 and Prasad, 1990) or present sporadically (Hussainy, 1967; Bisht and Das, 1985; Shardendu and Ambasht, 1988; Kant and Raina, 1990 and Fasihuddin and Kumari, 1990) or may be absent altogether (Ganapati, 1960; Gaur *et al.*, 1999). The literature on CO_2 system, in both temperate and tropical waters, has grown enormously (Chacko and Krishnamoorthy, 1954; Ganapati and Murthy, 1955; George, 1961; Sarkar and Rai, 1964; Sreenivasan *et al.*, 1964; Khan and Siddiqui, 1974; Munawar, 1970a; Sreenivasan, 1971b; Khan *et al.*, 1978; Unni, 1982; Datta *et al.*, 1983; Hegde, 1985; Marimuthu and Krishnamurthy, 1985; Singhal *et al.*, 1986; Kulshreshta *et al.*, 1987; Tripathi *et al.*, 1987; Haque *et al.*, 1988; Hosetti, 2002; Vajaykumar, 1999; Kumar, 2002a etc.). Ganapati (1960) has reported complete absence of CO_2 in certain tropical fresh waters. Ali and Khan (1979) and Haque *et al.* (1988) have also reported complete absence of CO_2 in tropical fresh waters in some seasons.

The absence of CO_2 is mainly due to its complete utilization during photosynthesis by algae or carbonates present did not allow the CO_2 to be produced in the bottom and column to reach to the surface (Ganapati,1960). Sometimes, continued acidification releases CO_2 and carbonic acid from the bicarbonates accompanied by loss of CO_2 from the system (Kaushik and Saksena, 1999). In the present study, CO_2 was found to be totally absent in all the samples collected during the study.

pH of water is considered to be one of the most important chemical factors affecting the productivity of any wetland. It has direct effect on fish and fisheries as well as on the growth and survival of other aquatic organisms. pH is a term used rather universally *to express the intensity of the acid or alkaline condition of a system.* pH of any aqueous system is suggestive of the acid-base equilibrium achieved by various dissolved compounds. In other words, pH *is a way of expressing the hydrogen ion concentration or more precisely, the hydrogen-ion activity.*

The variations in pH are linked with the chemical changes, species composition and life processes of animal and plant communities inhabiting the system. Maintenance of a constant pH in the body fluid at a given temperature is one of the important tasks of the regulatory systems for homoeostasis in aquatic animals (Alabaster and Lloyd, 1984). Hence, to achieve good fish production, pH of water should be monitored regularly to ensure its optimum range. It is widely accepted that the pH between 6.5 and 9.0 supports a good fishery. (Das *et al.*, 2001). pH is generally considered as an index to assess suitability of the environment. Webber and Stumm (1963) have concluded that the pH of the raw water sources mostly lies within the range between 6.5 to 8.5. The productive range of pH lies between 7.1 to 8.5 in the reservoirs (Sukumaran and Das, 2001). All inland waters in India lie in the alkaline range without much variation (Sreenivasan, 1972; Singhal *et al.*, 1986; Ghosh and George, 1989; Shastree *et al.*, 1991 and Khan *et al.*, 2000).

The ***alkalinity*** of water is *a measure of its capacity to neutralize acid.* The alkalinity, in natural waters, is mainly caused by three major classes of materials, which may be ranked in order of their association with high pH values. They are, *Hydroxides*, *Carbonates* and *Bicarbonates*. For most practical purposes, alkalinity due to other materials in natural water is insignificant and may be ignored. The role of alkalinity in the determination of the productive capacity of an aquatic environment has also been described by Phillipose (1959). He categorized inland waters into three types namely, *soft*, ***medium*** and ***hard waters.*** According to him, water with low alkalinity were comparatively less productive than the water with high alkalinity.

Hardness of water reflects the nature of the geological formation with which it has been in contact. It is derived largely from contact with the soil and rock formations. The total hardness is not a specific constituent of water but is a variable and complex mixture of cations and anions. It is predominantly contributed by Calcium and Magnesium along with some minor contributions by strontium, barium, zinc, manganese, aluminium and iron. It may be of temporary (carbonate) or permanent (non-carbonate) type. Mairs (1966) has found that the hardness and alkalinity are closely related to each other. It has been suggested that whenever hardness is lower than alkalinity, it is due to carbonates, and when the hardness is greater than total alkalinity, it is contributed mainly by bicarbonates. Unni (1983) has suggested that total hardness can be used as an indicator for classifying domestic pollution in water. Carbonate hardness is more sensitive to heat and precipitates readily at high temperature. Like alkalinity, the hardness is also an important parameter in decreasing the toxic effect of poisonous elements.

METHODOLOGY

For the analysis of free CO_2, total alkalinity and total hardness water samples were collected from surface of the wetlands directly with the help of a wide mouth bottle. Free CO_2 was determined by titrating 100ml water sample with N/44 NaOH solution using phenolphtalein as an indicator at the site itself. Alkalinity and total hardness were determined by the procedure and precautions given by APHA (1992). pH was determined with the help of Marconi's portable pen type digital pH-meter.

RESULTS

Free CO_2 was found to be absent in all the three wetlands during the study. The seasonal variations in the concentrations of total alkalinity, total hardness and pH are given in the Tables (6 and 8) and illustrated in Figs. 3 and 5.

The monthly values of alkalinity in terms of carbonate, bicarbonate and hydroxide alkalinity showed wide fluctuations in all the three wetlands. In CP-1 and CP-2, only carbonate and bicarbonate alkalinities were found, whereas in MP, carbonate, bicarbonate and hydroxide alkalinities were found during the course of study (Table 8).

The monthly values of carbonate alkalinity, at CP-1 and CP-2, were found to vary from 32.0 mg/L (Febuary, 2001) to 76.0 mg/L (May, 2001) and 26.0 mg/L (Febuary, 2001) to 84.0 mg/L (May, 2001) respectively (Table 8), whereas in MP, minimum of carbonate alkalinity was found in the month of January, 2001 (36.0 mg/L) and maximum during December 2000, (186.0 mg/L).

Bicarbonates varied from119.0 to 196.0 mg/L in CP-1 and from 115.0 to 182.0 mg/L in CP-2. At CP-1 minimum concentration was recorded during August, 2000 and maximum during July, 2001, whereas in CP-2, minimum concentration was recorded during March, 2001 and maximum during July, 2001.At MP the values of bicarbonates showed variations from 28.0 mg/L (February, 2001) to 80.0 mg/L (August, 2001), but it was found to be totally absent in some samples collected during post-monsoon and winter months of 2000 and summer and post monsoon months of 2001. In the absence of bicarbonates, in MP, hydroxide alkalinity was found to be present (Table 8). The hydroxide alkalinity values showed maximum concentrations (116.0 mg/L) in the month of November, 2001, and minimum (18.0 mg/L) during June, 2001 (Table 8).

The values of total hardness were found to vary between 124.0 to 320.0 mg/L in CP-1 and 130.0 to 392 mg/L in CP-2 (Table 8) In MP, the total hardness was recorded highest in the months of June and November, 2001 (390.0 mg/L) and lowest in July, 2001 (218.0 mg/L).

The pH of the surface waters varied from 8.4 to 9.2. in CP-1 and 8.4 to 9.1 in CP-2, whereas in MP, pH varied from 8.3 to 9.2 (Table 6). All the three wetlands, thus, showed the *alkaline* nature of water.

DISCUSSION

In the present investigations, free CO_2 was found to be totally absent in all the samples collected from three wetlands. Absence of free CO_2 in all the samples may be attributed to increased values of pH (8.4 or above). Similar observations have been reported by Jhingran (1975) and many others (Kaushik and Saksena, 1999). Singhal *et al.* (1985, 1986) have reported that free CO_2 and water temperature varied independently. They have also reported low values of free CO_2 when aquatic vegetation was more abundant. Ganapati (1960) has reported total absence of free CO_2 due to its complete utilization during photosynthesis by algae or carbonates present did not allow the CO_2 to be produced in the bottom and column to reach to the surface. Natural tropical water bodies and wetlands usually show a wide range of fluctuations in total alkalinity values depending upon the location, season, micro- and macrophyte populations, rainfall, washermen's activity and nature of bottom deposits etc. (Kaushik and Saksena, 1999). Alkalinity is important for aquatic life in freshwater system because it equilibrated pH changes that occur naturally as a result of photosynthetic activity of chlorophyll bearing vegetation. Carbonates, bicarbonates and hydroxide form the basic components of alkalinity in the wetlands under study. The range of total alkalinity in Indian inland waters varied from 40 to over 1000 mg/L (Jhingran, 1975). In the present study of these wetlands, total alkalinity varied from 94 to 294 mg/L (Table 8).

The chemical buffering of the system is brought about by carbon dioxide - bicarbonate - carbonate complex. This system actually forms the carbon sources of phytoplankton during carbon assimilation. In these wetlands, the alkalinity was found to be due to mainly calcium and magnesium cations and form either carbonates, bicarbonates or hydroxides.

In the present study, *carbonate alkalinity* was recorded in all the samples (Table 8). Verma and Shukla (1968), Sreenivasan (1972), Shardendu and Ambasht

(1988), Kaushik *et al.* (1989), Fasihuddin and Kumari (1990), Kant and Raina (1990), Prasad (1990) and Khan *et al.* (2002) have reported similar observations with regards to seasonal variations in carbonate alkalinity. During photosynthesis, bicarbonates are broken and carbonates are released (Welch, 1952). Thus, it is obvious that the changes in the phytoplankton number must be directly related to the changes in the carbonate concentration. However, no significant direct relationship was obtained between carbonates and phytoplankton in the present study.

Bicarbonate alkalinity is the main constituent to the total alkalinity and is invariably present in waters in which photosynthesis is actively taking place (Chourasia and Adoni, 1985). In the present investigations, it was found to decrease in certain months of post-monsoon and winter seasons and increase during summer and monsoon months (Table 8). Very different results have been reported by Ganapati (1956), Verma (1969), Zutshi and Vass (1978), Bisht and Das (1985), Chourasia and Adoni (1985) Kaushik *et al.* (1989, 1991ab), Haque (1991) and Gaur (1998). Further, increased bicarbonate values during winter season and decreased values during summer and monsoon months have been reported by Qadri and Yousuf (1980). All these reports showed a bimodal pattern, but, in the present study, only one peak of high magnitude appeared in the summer that continued in monsoon months (Table 8 and Fig. 5). The increase or decrease in bicarbonate content may be ascribed to the photosynthetic or respiratory activity of the algae respectively.

Ghosh and George (1989) have reported that all the waterbodies with a pH range of 7.0 to 9.0 always show a very high bicarbonate concentration. In the present investigations, similar situation has been observed in CP-1 and CP-2. In case of MP, the bicarbonate alkalinity was found to be absent in certain months of the study and instead -OH (*hydroxide alkalinity*) was observed during those months (Table 8). This condition appears only when the phenolphthalein alkalinity (CO_3) is found greater than the half of the total alkalinity or twice the methyl orange alkalinity (Theroux *et al.*, 1943). In all the three wetlands, carbonate alkalinity increased and decreased along with the pH of the water, being highest when photosynthesis was most pronounced and lowest when photosynthetic process was less active .

In the present study, it was interesting to note that the pH values were always found 8.4 or more throughout the period of study (Table 6). It is well know that changes in the pH of water bring about changes in the structural and functional variations in the organisms of the water body. Measurements of hydrogen-ion-concentration is an important mean of understanding the nature of chemical conditions, which prevail in the aquatic ecosystem (Welch, 1952). It was observed that the pH values of CP-1 and CP-2 followed a specific seasonal trend from August to December, 2000 then showed fluctuations during remaining period of study.

According to the classification given by Venkateshwarlu (1983), these wetlands can be placed under *Alkaliphilous* (pH from 7.5 to 9.0) and *Alkalibiontic* (pH above 9.0). Lowered pH values at CP-1 and CP-2, during monsoon months having cloud covers and during post-monsoon months with decreased photoperiods, were found to be controlled by the decreased photosynthetic activity. Contrary to CP-1 and CP-2 , MP showed highest values during monsoon and post-monsoon months of 2000 and post-monsoon months of 2001, and low during March and August, 2001 (Table 6)

A fall in pH during monsoon months was also recorded by Shardendu and Ambasht (1988) and Kaushik *et al.* (1989, 1991). Also the cloudy atmosphere reduces the pH considerably. Ellis (1937) and Swingle (1967) have suggested that waters with hydrogen ion concentrations ranging between (6.5 to 9.0) are most suitable for fish production. Verma and Shukla (1968) believed that alkaline waters support large amount of biota. Bell (1971) has stated that pH of 6.5 to 9.0 appears to provide adequate protection to the life of freshwater fish and bottom dwelling fish food organisms. In waters having low pH values, fishes and other aquatic organisms get prone to attacks of parasites and diseases. Ohle (1938) opined that pH above 10 and below 4.8 have a detrimental effect. According to Swingle (1967), if waters have pH less than 6.5 or above 9.5 for a prolonged period, reproduction and growth of fish would diminish. As pH increases above 8.3, there will be absence of CO_2, which is required for the growth of phytoplankton (Theroux *et al.*, 1943).

Spence (1967) has stated that alkalinity and pH are closely connected with an accurate measure of the trophic status of lake water. On the basis of Spence (1967) assumption, all the three wetlands under study are in increasing order of eutrophy. The decrease in pH values during different months was probably due to release of anaerobic waters affected by the decomposition of concentrated organic matter and the respiration of biota, while increase in pH values was mainly due to rise in carbonate alkalinity, resulting from photosynthetic activity of the phytoplankton and other green aquatic plants. Sreenivasan *et al.* (1964) has also given the similar reasons.

Hardness to water *is imparted by alkaline earth metal cations*, mainly *calcium* and *magnesium* present in it. Higher values of total hardness were recorded in the winter season and post-winter months in all the wetlands (Table 8). Ecologically, temporary hardness play a key role in buffering capacity, thus neutralizing an offset in pH, due to addition of acidic products by human activities as in the case of MP in this study where many stains, chemicals, dyes and detergents are used by the washermen daily. The higher values observed in the present study are mainly due to concentrations of carbonates and bicarbonates in combination with Ca and Mg which enter along with the surface run-off from the surrounding fields during rainy season and sewage discharge into these wetlands from neighbouring village. All the three wetlands showed same trend of fluctuations. Similar findings have been reported by Singh *et al.* (1982), Chattopadhya *et al.* (1984), Haque (1991) and Vijaykumar *et al.* (1999). According to Sreenivasan (1974) and Spence (1967), these wetlands can be regarded most suitable and productive for the growth of fish and fisheries as they are having hardness above 15.0 mg/L. Swingle (1967) has also reported that hardness less than 5.0 mg/L gives slow growth, distress and even leads to death. Further, Sawyer (1960) has classified waters on the basis of hardness into three categories, *soft* with hardness ranging from 0.0 to 75.0 mg/L, *moderately hard* with hardness ranging from 75.0 mg/L to 150.0 mg/l and *hard* with hardness ranging from 150.0 to 300.0mg/L. Thus Vihar Lake at Bombay (Hussainy, 1967); Amarvathy, Manimuthae, Aliyars Perinchani, Triurmoorthy, Sandynulla and Pykara reservoirs in Tamil Nadu (Sreenivasan, 1970) and Swetganga in west Bengal (Jana and Sarkar, 1971) are *soft* waterbodies. Stanley, Bhavani Sagar, Vidur, Gomukhi and Ponds reservoirs at Madras (Sreenivasan, 1970) and Bhimtal at Nainital (Bisht and Das, 1985) are *soft to moderately* hard. Krishnagiri reservoir at Madras (Sreenivasan, 1970), lower lake at Bhopal (Valecha *et al*., 1987) are *moderately hard.* Santhaur reservoir at Madras. (Screenivasan, 1970) is *moderately hard to hard.* Odathurai tank in Coimbatore (Sreenivasan, 1972) is hard. Nainital lake at Nainital (Bisht and Das, 1985), certain water bodies of Kashmir (Yousuf and Shah, 1988) and Chandanpura pond and Vivek Nagar pond at Gwalior (Kaushik *et al*., 1989, 1990, 1991a, b) are *hard to very hard.* In the present study of these wetlands, after following the Sawyer's (1960) classification, the water of (CP-1, CP-2 and MP) wetlands is categorized under *moderately hard to hard.*

(iii) – SOLIDS IN THE WETLANDS

In any water body *total solids* (*T.S.*) are represented by *total dissolved solids* (*T.D.S.*) and *total suspended solids* (*T.S.S.*). Total solids in water are due to inorganic and organic substance including both dissolved and suspended particles like silt, clay and plankton etc. Higher amounts of total solids cause turbidity and so reduce the light penetration affecting water quality indirectly and imbalance the aquatic life. In the present study, *T.D.S.*, *T.S.S.* and *T.S.* have been analyzed in order to determine the relative effect of these variables.

All polluted water bodies have higher quantities of total solids. Many workers have reported wide variations in the T.S. from different parts within and outside the country (Rawson, 1951; Welch, 1952; Hutchinson, 1957, 1975; Vollenweider, 1969; Kemp, 1971; Wetzel, 1975; Trivedi and Goel, 1982; Kaushik *et al.*, 1989; Shastree *et al.*, 1991; Mishra *et al.*, 1997; Kaushik and Saksena, 1999; Vijaykumar, 1999; Kumar, 2002; Verma and Sharma, 2002 etc.).

Total Dissolved Solids (T.D.S.) in water comprise mainly of inorganic salts and small amount of organic matter. Generally, carbonate, bicarbonate, chloride, sulphate, nitrate, sodium, potassium, calcium and magnesium contribute total dissolved solids T.D.S. It originates from natural sources and depends upon location, geological nature, pond basin, drainage, rainfall, bottom deposit and inflow water. The T.D.S. has been proved as a very useful parameter in determining the productivity of inland waters (Hutchinson, 1975; Wetzel, 1975). Sometimes usefulness of mineral content of T.D.S. is considered as *"a rough indicator of edaphic conditions which, in some measures, affect the productivity of lakes"* (Rawson, 1951). According to Vollenweider (1969), T.D.S. probably bear the same relation to nutrient loading as standing crop of fishes bears to actual fish production. Kemp (1971) has stated that in the classification of waters with respect to productivity the amount of T.D.S. present in them is of greater importance than their chemical composition. The dissolved solids are usually the result of solvent action of water on both inorganic as well as organic solids. The inorganic substances include metals and minerals etc., while the organic dissolved constituents are the product of the decay and decomposition of the bodies of plants and animals as well as their excretory matter and refuse etc.

Total Suspended Solids (T.S.S.) in water bodies are contributed by particles of different sizes ranging from coarse to fine colloidal particles of various organic complex and plankton. It includes the substances, which impart turbidity to water thereby reducing transparency. T.S.S. in these wetlands consists of inorganic and organic particles. Inorganic solids such as clay, silt and other soil constituents are common in these wetlands. Among organic materials such as plant fibres and biological solids, algal cells, bacteria etc. are also common constituents of these wetlands. These materials are often regarded as natural contaminants resulting from erosive action of water flowing over surfaces.

METHODOLOGY

Samples of water were collected from the surface waters of these wetlands and analysed in the laboratory for T.S, T.D.S. and T.S.S. following the methodology and precautions given in the Welch (1952), Trivedi and Goel (1984) and APHA (1992).

RESULTS AND DISCUSSION

In the present study, ***T.S.*** were found to fall in the range of 1200to 2768 mg/L, 1050 to 2750 mg/L and 1700 to 6000 mg/L at CP-1, CP-2 and MP respectively (Table 7 and Fig. 4). At CP-1 higher values were noted during post-monsoon, 2000 and then from summer to post-monsoon, 2001, whereas low values were recorded in the rest of the months. In the case of CP-2, the higher values of T.S. were recorded in the months of monsoon and post-monsoon (2000 and 2001), and low in the rest of the months. In the case of MP, higher values of T.S. were recorded in the winter, summer, monsoon and post-monsoon months of 2001, and low in rest of the months.

Higher values of T.S. during monsoon months may be due to increased inflow of suspended solids in the form of eroded soil particles from the shoreline as well as with the surface run-off coming from the surrounding catchment areas.

As soon as monsoon recedes, the water filled in the adjoining villages and agricultural fields during rains makes its way to these wetlands and results in the high concentration of T.S. in the post-monsoon months. In the case of MP, higher values were recorded in the winter months, may be due to relatively disturbed water conditions resulting from the occasional rains in these wetlands.

Results of the work done on ***T.D.S.*** are shown in Table 7 and Fig.4. Lowest value of T.D.S. (600mg/L) was recorded in March 2001 and highest, (2170 mg/L) in May, 2001 at CP-1. At CP-2, lowest value (435 mg/L) was recorded in October, 2000 and highest (1800 mg/L) in July, 2001.In case of M.P. the lowest value 1300 mg/L was found in the mouth of May, 2001 and highest values (5600 mg/L) in the month of April, 2001.

In the present study, T.D.S. showed higher values during summer and monsoon months at CP-1, CP-2 and MP. High values may be due to non-utilization of T.D.S. because of less presence of phytoplankton and other green aquatic organisms, which could utilize it. Fluctuations in T.D.S. in these three wetlands are considerable with an extremely well defined seasonal pattern (Table 7 and Fig. 4). Amplitude of fluctuations in T.D.S. corresponding to the concentrations of different ions was found to be low and high. High T.D.S. might be due to mixing of sewage and surface run-off water from the catchment areas during monsoon seasons and non-utilization in summer season in these wetlands. The similar findings have also been reported by Mishra *et al.* (1997). Factors such as nature of bottom deposits, area of drainage, rainfall, wind and biota causing changes in the ionic composition, affect the concentration of T.D.S. High values of T.D.S. during summer was found to be mainly due to rapid decomposition rate and release of nutrients from the sediments with increase in temperature during summer. Shastree *et al.* (1991) reported high concentration of T.D.S. during summer months and attributed it to water loss due to evaporation, which resulted in the concentration of T.D.S. load.

Waters with high T.D.S. are highly productive than those with low values and, therefore, T.D.S. is considered as an *index of productivity.* But high concentration of T.D.S. may sometime produce distress in cattle and live stock (Kaushik and Saksena, 1999). Statistically, Transparency and T.D.S. showed significant inverse relationship (Fig. 15) at CP-1 ($r = -0.566$; $p < 0.05$), at CP-2 ($r = - 0.491$; $p < 0.05$) and at MP ($r = -0.355$, $p < 0.05$).

The ***T.S.S.*** show a peculiar presence and distribution in all the three investigated wetlands. In case of CP-1, T.S.S. were found to be high during monsoon months of 2000 and 2001. Highest value was recorded in the month of August, 2000 (1508 mg/L) whereas the lowest in the month of November, 2001 (375 mg/L). CP-2, showed higher values in the monsoon and post-monsoon months of 2000, August 2001 and summer months of 2001. The highest value (1915mg/L) was recorded in the month of May, 2001 and lowest (127 mg/L) was in the month of December, 2000.In case of M.P, the values fluctuated from 60 mg/L in September, 2001 and November, 2001 to 1000 mg/L in July, 2001. The higher values were recorded in the summer and post-monsoon months of 2000 and 2001, whereas rest of the months showed lower values. (Table 7).

Higher values during monsoon seasons may be because of silt, clay and other particles entering into these wetlands along with surface run-off water during rains and low values in rest of the months were found to be due to sedimentations. Similar findings have been reported by Kaushik and Saksena, (1999). At CP-2, increased values of T.S.S. during summer was found to be due to disturbed condition in these shallow waterbodies and abundance of phytoplankton (Table 17a). Higher values of T.S.S. may also be the result of human use of these waters in the form of domestic wastes.

In case of MP, the higher values of T.S.S. in summer and post-monsoon months may be due to various factors responsible for it. This wetland is mostly used by the washermen for cleaning clothes using certain chemicals, stains and other colouring substances which help in increasing T.S.S. in this wetlands.

Further, cattle's and other livestock prefer to bath during high peaks of summer in these wetlands. As a result of it the bottom sediments become disturbed resulting in the concentration of suspended materials in the water column showing high values of T.S.S. Higher values of T.S.S. were also reported by Verma and Sharma (2002) in summer and monsoon months. Statistically, it was found that CP-1 and CP-2 showed significant inverse relationship (Fig. 16) between T.S.S. and Transparency ($r = -0.519, p < 0.05; r = -0.614, p < 0.05$) but non-significant relation was found at MP ($r = 0.153, p < 0.05$).

Table 7
Monthly variations in Total Solids (mg/L), Total Dissolved Solids (mg/L), Total Suspended Solids (mg/L) and Extinction Coefficient (cm) in Wetlands.

Months ↓	Total Solids (T.S.)			Total Dissolved Solids (T.D.S.)			Total Suspended Solids (T.S.S.)			Extinction Coefficient (E.C.)		
Wetlands →	CP-1	CP-2	MP	CP-1	CP-2	MP	CP-1	CP-2	MP	CP-1	CP-2	MP
August, 2000	2768.0	2584.0	2160.0	1260.0	1673.0	1980.0	1508.0	911.0	80.0	0.098	0.112	0.112
September	1890.0	2750.0	2100.0	820.0	1023.0	1925.0	1070.0	1727.0	75.0	0.099	0.116	0.099
October	1590.0	1640.0	2750.0	685.0	435.0	1850.0	905.0	1205.0	800.0	0.093	0.099	0.081
November	1600.0	2610.0	1700.0	1120.0	880.0	1300.0	480.0	1130.0	400.0	0.104	0.113	0.051
December	1500.0	1130.0	2100.0	1017.0	1003.0	1910.0	483.0	127.0	190.0	0.060	0.664	0.060
January, 2001	1680.0	1550.0	2800.0	1180.0	640.0	2490.0	500.0	910.0	210.0	0.060	0.063	0.130
February	1286.0	1250.0	2700.0	800.0	720.0	2515.0	486.0	530.0	185.0	0.044	0.065	0.126
March	1200.0	1190.0	3000.0	600.0	480.0	2800.0	600.0	710.0	200.0	0.048	0.047	0.110
April	1865.0	1630.0	6000.0	1200.0	760.0	5600.0	665.0	890.0	400.0	0.064	0.063	0.120
May	2720.0	2680.0	1750.0	2170.0	765.0	1350.0	550.0	1915.0	400.0	0.126	0.094	0.064
June	2630.0	2480.0	2900.0	1733.0	1000.0	2400.0	897.0	1480.0	500.0	0.173	0.136	0.053
July	1800.0	2550.0	4000.0	1000.0	1800.0	3000.0	800.0	750.0	1000.0	0.117	0.106	0.048
August	2660.0	2580.0	2200.0	1500.0	1250.0	2120.0	1160.0	1430.0	80.0	0.130	0.070	0.047
September	1800.0	1650.0	2070.0	720.0	1180.0	2010.0	1080.0	470.0	60.0	0.076	0.066	0.045
October	1630.0	1540.0	2700.0	1069.0	795.0	2000.0	630.0	745.0	700.0	0.067	0.080	0.058
November	1545.0	1050.0	1760.0	1170.0	700.0	1700.0	375.0	350.0	60.0	0.067	0.058	0.049
December	1566.0	1118.0	2400.0	1060.0	600.0	1950.0	566.0	518.0	450.0	0.056	0.048	0.097

CP-1: Chharat Pond 1; CP-2: Chharat Pond 2; MP: Medical Pond

Table 8

Monthly variations in Hardness (mg/L), Carbonate (mg/L), Bicarbonate (mg/L) and Hydroxide (mg/L) in Wetlands.

Months ↓	Hardness			Carbonate (CO_3)			Bicarbonate (HCO_3)			Hydroxide (OH)		
Wetlands →	CP-1	CP-2	MP	CP-1	CP-2	MP	CP-1	CP-2	MP	CP-1	CP-2	MP
August, 2000	142.0	140.0	240.0	52.0	56.0	120.0	119.0	126.0	40.0	0.0	0.0	0.0
September	147.0	135.0	242.0	48.0	54.0	88.0	133.0	132.0	62.0	0.0	0.0	0.0
October	186.0	178.0	272.0	48.0	52.0	104.0	131.0	134.0	0.0	0.0	0.0	33.0
November	196.0	190.0	284.0	54.0	40.0	114.0	137.0	137.0	0.0	0.0	0.0	30.0
December	188.0	210.0	376.0	37.0	36.0	186.0	143.0	129.0	0.0	0.0	0.0	40.0
January, 2001	296.0	286.0	356.0	39.0	46.0	36.0	132.0	151.0	60.0	0.0	0.0	0.0
February	276.0	258.0	334.0	32.0	26.0	66.0	139.0	127.0	28.0	0.0	0.0	0.0
March	320.0	312.0	366.0	54.0	49.0	90.0	138.0	115.0	0.0	0.0	0.0	30.0
April	292.0	322.0	354.0	52.0	50.0	96.0	147.0	142.0	0.0	0.0	0.0	36.0
May	312.0	392.0	376.0	76.0	84.0	76.0	171.0	174.0	0.0	0.0	0.0	40.0
June	244.0	310.0	390.0	71.0	64.0	122.0	168.0	178.0	0.0	0.0	0.0	18.0
July	162.0	152.0	218.0	40.0	38.0	100.0	196.0	182.0	0.0	0.0	0.0	37.0
August	124.0	130.0	244.0	48.0	40.0	130.0	149.0	146.0	80.0	0.0	0.0	0.0
September	188.0	184.0	294.0	44.0	37.0	180.0	148.0	151.0	61.0	0.0	0.0	0.0
October	264.0	260.0	374.0	47.0	50.0	120.0	134.0	138.0	0.0	0.0	0.0	90.0
November	260.0	250.0	390.0	56.0	42.0	178.0	140.0	140.0	0.0	0.0	0.0	116.0
December	275.0	258.0	380.0	39.0	43.0	126.0	146.0	139.0	0.0	0.0	0.0	80.0

CP-1: Chharat Pond 1; CP-2: Chharat Pond 2; MP: Medical Pond

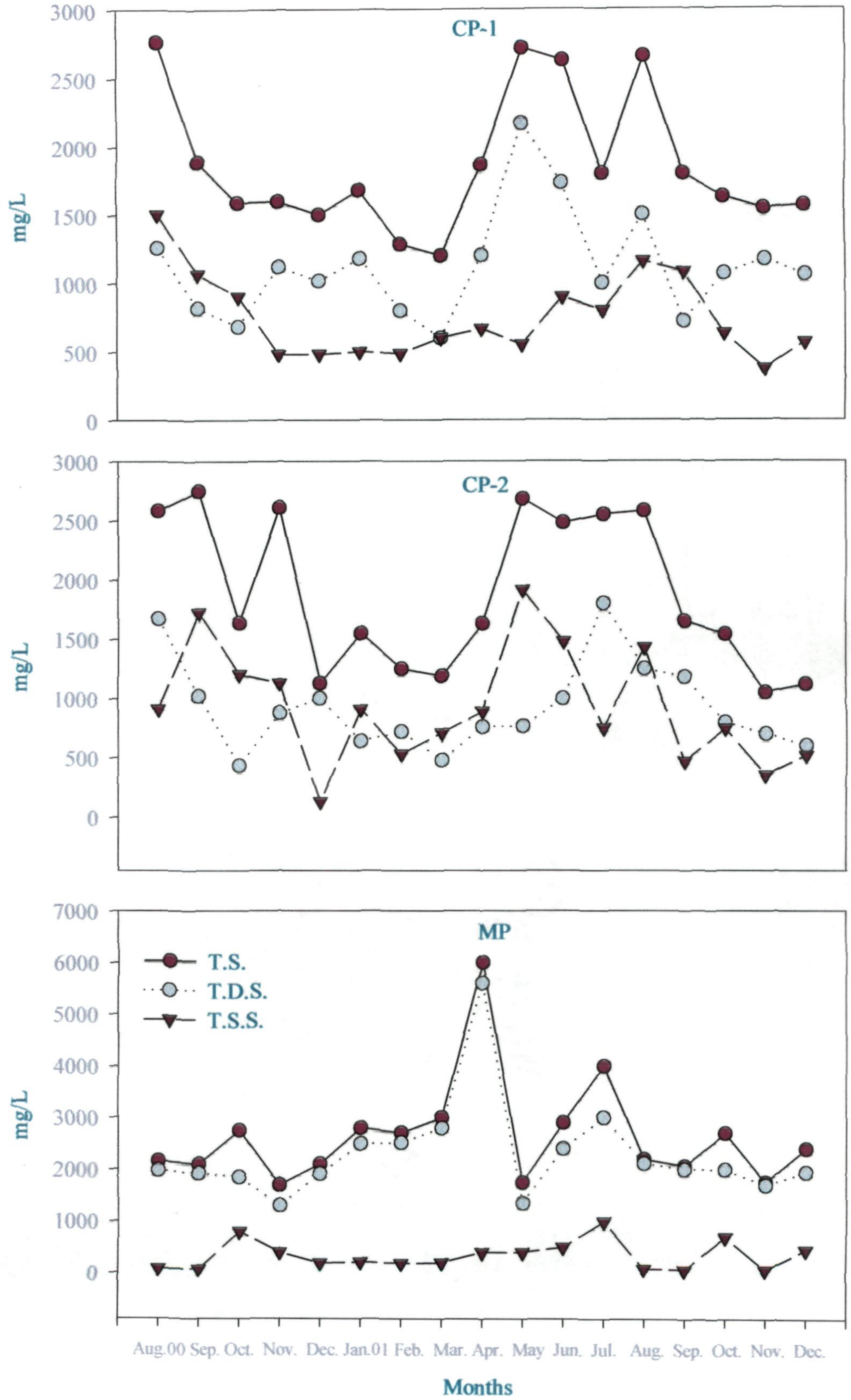

Fig. 4. Monthly variations in Total Solids (T.S.), Total Dissolved Solids (T.D.S.) and Total Suspended Solids (T.S.S.) at CP-1, CP-2 and MP Wetlands.

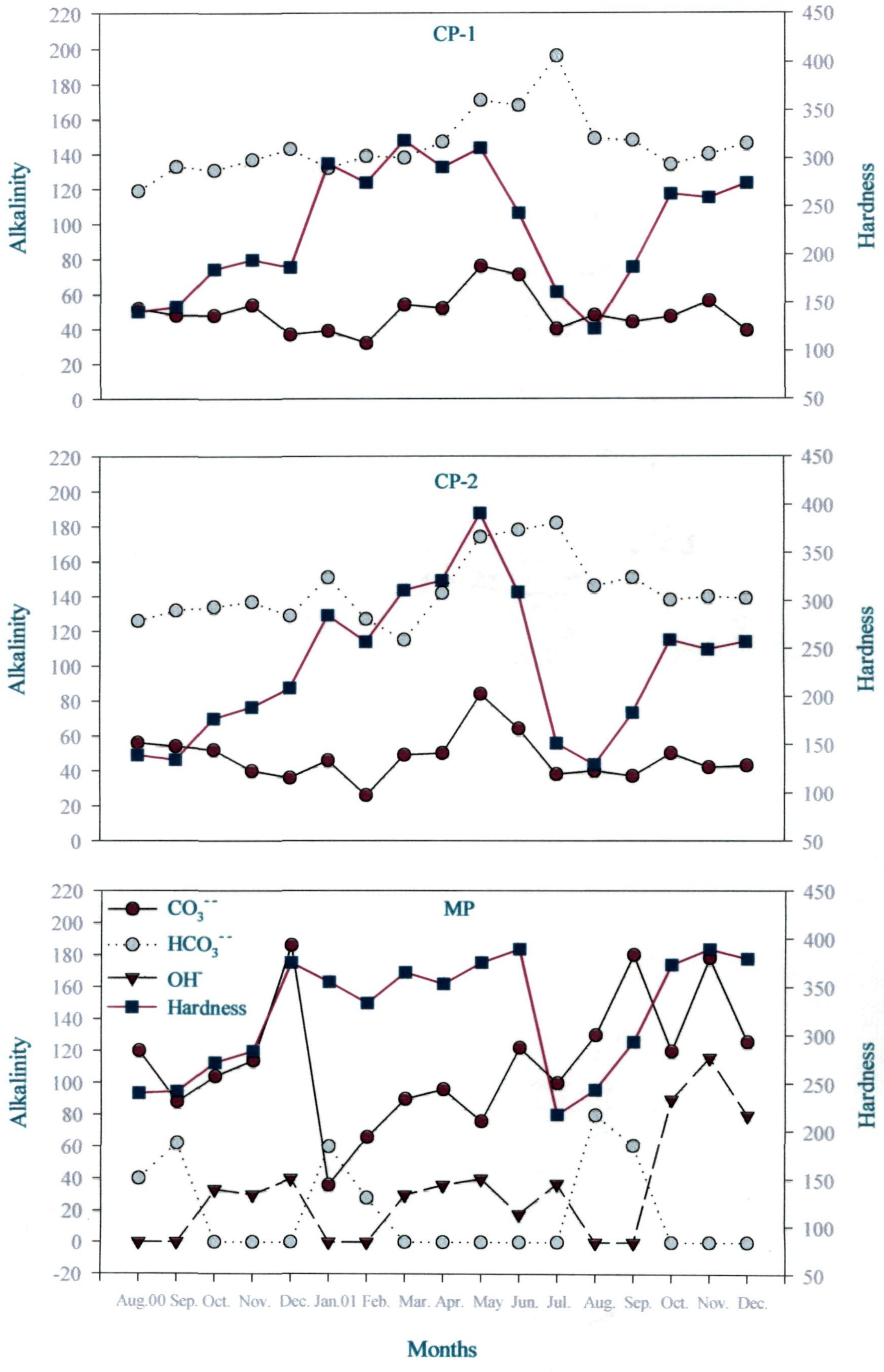

Fig. 5. Monthly variations in Hardness (mg/L) and Alkalinity (mg/L) at CP-1, CP-2 and MP Wetlands.

(iv) – IONIC COMPOSITION IN THE WETLANDS

Anions and Cations form the ionic composition of water. All waters contain, both organic and inorganic dissolved solids. The inorganic solids, when in solution, consists *anions* like *carbonates, bicarbonates, chlorides, sulphates, silicates, phosphates, nitrates, and nitrites* etc., and *cations* like *calcium, magnesium, iron, sodium and potassium* etc. They combined with each other to form compounds. These ions play a very important role in the life of aquatic flora and fauna. They have been regarded as an index of productivity (Moyle, 1949; Northcote and Larkin, 1956; Sarkar and Rai, 1964). A great deal of literature exists on ionic composition of temperate waters. Important contributions are those of Birge and Juday (1911), Maucha (1932), Ohle (1935) and Lohammer (1938), Davis (1962) and Harris (1967). In Indian tropical waters, Khan and Qayyum (1966 b), Khan and Siddiqui (1974) and Khan *et al.* (1978) have studied in detail the ionic composition of fish ponds of Aligarh. Further, Munawar (1970,1972), Chakrabarty *et al.* (1959), Saha *et al.* (1971), Mathew (1975), Ali and Khan (1979), Unni (1982), Hegde (1985) and Trivedi *et al.* (1985), Kaushik *et al.* (1989, 1990, 1991a), Haque (1991), Shastree *et al.* (1991) Thrash *et al.* (1994) Kappa (1993), Kumar (1995,2002), Raju and Durain (1996), Khan *et al.* (1999,2002), Gaur *et al.* (1999), Kumar (2002), Hosetti (2002) have also contributed from different parts of the country. Only Calcium (Ca) and Magnesium (Mg) among cations and Chloride (Cl) and Sulphate (SO_4) among anions were analysed and studied here in this chapter. The rest of the anions like Phosphate-phosphorus (PO_4-P), Silicate (SiO_3), Nitrate-nitrogen (NO_3-N) and Nitrite-nitrogen (NO_2-N) are discussed in the following chapter.

METHODOLOGY

Samples from the surface waters were collected for the analysis of these ions over a period of seventeen months (from August, 2000 to December, 2001). Analyses were made as soon as possible after transporting the samples in the plastic canes to the laboratory for chemical analysis. Ca, Mg and Cl. were estimated by titrimetric methods following the methods and precautions given by Trivedi and Goel (1984) and APHA (1992). Sulphate was analysed by turbidimetric methods given by Trivedi and Goel (1984).

RESULTS

Wide seasonal and monthly fluctuations in Ca, Mg, Cl and SO_4 are given in (Table 9) and illustrated in (Figs.6 and 7)

The ***calcium*** content varied from a minimum 36.10 mg/L (August, 2000) to a maximum of 102.60 mg/L (March, 2001) in CP-1 and from 34.20 mg/L (July, 2001) to a maximum of 120.24 mg/L (May, 2001) in CP-2 (Fig. 6). It varied from a minimum 34.00 mg/L in (August, 2000) to a maximum of 98.19 mg/L during (November, 2001) in M.P. Higher values of Ca were found mainly during winter and summer seasons and low in monsoon months. It starts increasing gradually in the post-monsoon months in all the three wetlands (Table 9).

Magnesium concentrations showed wide fluctuations in all the three ponds (Table 9 and Fig. 6). In CP-1 it varied from 6.77 to 25.34 mg/L, the highest concentration was recorded in the month of May, 2001, and lowest in August, 2001. In CP-2, it varied from 6.41 to 22.39 mg/L, the highest concentration was recorded in the month of May 2001 and lowest in September 2000. Whereas in MP, the lowest concentration (24.40mg/L) was recorded in the month of July, 2001 and highest (58.53 mg/L) in June, 2001 (Table 9).

The ***chloride*** content of these wetlands was found to vary from 56.00 to 423.00 mg/L at CP-1 and from 56.00 to 471.00 mg/L at CP-2. In MP, it fluctuates from 50.00 to 318.00 mg/L (Fig. 6). Chloride concentrations were found increasing in the post-winter months reaching to a maximum in the summer. The concentration declines in the monsoon months due to incoming rain water which causes dilution. Again it starts increasing during post-monsoon and winter months of 2001.

The concentration of ***sulphate*** recorded from the wetlands under study, ranged between 32.00 to 179.00 mg/L at CP-1; 29.00 to 164.00 mg/L at CP-2 and 40.00 to 164.00 mg/L at M.P (Table 9 and Fig.7). Recorded values showed low concentration during August, 2000 to January, 2001 in all the three wetlands. CP-1 and CP-2 also showed decreased values during March and September to December, 2001 (Table 9). Higher values were recorded during rest of the period in almost all these wetlands.

DISCUSSION

Ionic composition of a water body plays a very important role in the ecology of freshwater organisms, particularly of phytoplankton population as has been emphasized by Lund (1965). Ionic composition of the ponds depends mainly on relatively unmodified supply of ions from rainwater (Khan,1969) and drainage (Haque, 1991).

Calcium is one of the essential cations, found in natural water bodies. It triggers biological productivity (Ohle, 1938). The wide variations in calcium content in natural waters lead to a noted German Limnologist, Ohle (1938), to give following classification of water bodies.

(i) Waters with Ca >10 mg/L – ***Poor***,

(ii) Waters with Ca 10 mg/L – 25 mg/L – ***Medium***, and

(iii) Waters with Ca > 25 mg/L – ***Rich***.

According to above classification, the present wetlands, CP-1, CP-2 and MP, fall under the category of calcium rich waters.

The content of Ca is one of the variables in fresh waters on which faunistic differences can be based, as it is required in small quantities for phytoplankton growth. The lack of this cation may promote dystrophy decreasing the rate at which organic substances are precipitated, mineralized and recycled for use by primary producers. Ca occurs mostly in combination with carbonates and sometimes with chloride, silicates and sulphates.

The main sources of calcium in these wetlands appear to be terrestrial origin, being derived by weathering of calcareous materials and domestic effluents entering into the wetlands from adjoining village and colonies. Also cattle and other livestock use these wetlands and add Ca level by bathing and by their excretory substances.

High values of Ca during summer and in some months of winter at CP-1 and CP-2 were mainly due to evaporation of water resulting in the concentration of this cation in both the wetlands. Further, it is released during decomposition of dead plants and animals. Low values during monsoon and post- monsoon months, have also been reported by several workers (Khan and Siddiqui,1974; Ramanibai and Ravichandran, 1987; Kant and Raina, 1990;Gaur *et al.*,2001 and Khan *et al.*, 2002).

Species of diatoms were found in abundance in all the studied wetlands having rich concentration of calcium. Vollenweider (1950) has also reported that a number of diatoms grow best with high calcium contents. Ca has been also recognized as the essential micronutrient for the green algae, and as macronutrient for blue-green algae (Goldman, 1965). Both types of algae were found in abundance in these wetlands. (Table 12 to14) which indicate that Ca was never a limiting factor for the production of green and blue-green algae in these wetlands.

The water of these wetlands can be said to be '*poor*' during August to September, 2000 and July to August, 2001 at CP-1 and CP-2 and form August to September 2000 in M.P. It was "*Good*" during October to December, 2000 at CP-1, CP-2 and MP and "*Very Good*" during summer months at all the three wetlands, when classified according to Calcium contents of waters (Juday *et al.*, 1938 and Upadhayaya, 1955).Chacko and Ganapati (1949) have stated that a minimum of 650.00 mg/L of calcium is essential for "*Really Good Production*". But this amount of calcium appears to be too high, as the concentration of calcium in all the three wetlands investigated here was never found more than 120 mg/L (Table 9).

High concentrations of Calcium in summer have been reported by Ramanibai and Ravichandran (1987) and Kaushik *et al.* (1991a), whereas low values were obtained by Khan and Siddiqui (1974) during rainy season. Kant and Raina (1990) have also reported low values during winter months.

Magnesium (Mg), an important constituent of chlorophyll, was found in high quantities in all the three wetlands investigated. According to Wetzel (1975), Mg is required by both micro and macro green algae to build its chlorophyll. It is also required in enzymatic transformation, especially transphosphorylations of algae, fungi and bacteria.

The depletion of Mg acts as limiting factor for the growth of phytoplankton and reduces the number of phytoplankton. Statistically, Mg and Phytoplankton (CP-1 , $r = -0.052$, $p<0.05$; at CP-2, $r = 0.567$, $p<0.05$ and at MP, $r = 0.139$, $p< 0.05$) showed positive correlation at CP-2 and MP and negative at CP-1. According to (Welch 1952), Mg is usually found in combination with CO_3 and HCO_3 and sometimes with sulphates and chlorides.

The concentration of Mg in Indian Inland waters ranged from 2.45 to 107.0 mg/L (Goel *et al.,* 1986; Khatavakar *et al.,* 1995). In the present investigations, Mg. Concentration was found in the range of 6.41 to 58.53 mg/L (Table 9), which is enough for the planktonic growth in these wetlands. Highest concentration was recorded in the months of summer and lowest in the monsoon month. Similar observations have been reported by Khan and Siddiqui (1974), Shastree *et al.* (1991) and Haque (1991) in North Indian freshwater bodies.

Chloride is relatively conservative and undergoes only minor spatial and temporal fluctuations within water body through biotic utilization or biotically mediated environmental changes. Natural waters contain low chloride than bicarbonates and sulphates. Large content of Cl in fresh waters is an indication of organic pollution (Ganapati, 1960). Among anions, Cl was also detected and found to be most distributed in all these three wetlands. (Table 9 and Fig. 6).

Maximum values of Cl were recorded in June, July, November and December, 2001 in all the wetlands, where as it was low in concentration during almost all the months of 2000 in all the wetlands. Chlorides in waters are generally found in combination of Na, K, and Ca (Vijaykumar 1999). In the present study, Cl was found to be contributed to these wetlands by sewage discharge which enter in these wetlands from adjoining residential localities. It may also be contributed from irrigation canals to these wetlands. In the case MP pond it also comes from the chemicals and stains used by washermen's activities.

The increase in Cl content during summer months in the present study, may be attributed to higher evaporation rate because of ambient temperature and maximum human activities. Many workers (Chourasia and Adoni, 1985; Kaushisk *et al.*,1989, 1991a) have reported similar observations. In the present study, higher values during

June, July, November and December, 2001 were found to be due to incoming surface runoff which might had brought animal and human excreta and wastes along with salts from the catchment area containing large amounts of chlorides. Higher values of Cl may also be correlated with maximum growth of phytoplankton and zooplankton along with bottom biota. In the present study, a higher significant positive correlation is obtained at CP-1 indicating that Cl may play a very significant role in the production and growth of phytoplankton. Verma and Shukla (1970) and Kaushik *et al.*(1989,1991a) have also reported similar findings. They have observed higher values of Cl when maximum growth of plankton and bottom biota occurred whereas Sarkar and Rai (1964) have reported that Cl is not used in plant growth but accumulated in large amounts due to input of pollution load. Increased concentration of Cl is always regarded as an indication of eutrophication (Hynes, 1963) and pollution due to sewage (Chourasia and Adoni, 1985) as also found in the present investigations

Lower concentration of Cl in winter seasons can be attributed to the sedimentation and human disturbance. Kaushik *et al.* (1989, 1990, 1991a), Kant and Raina (1990) and Haque (1991) have reported similar views regarding seasonal variations in Cl content in lentic water bodies. Seasonal variations in the concentrations of highly soluble Cl may also be due to presence or absence of relative amount of Cl in incoming sewage water as well as in rain waters.

From the present discussion one may conclude that the data collected during a particular season or month many not give a true picture of the ionic composition of a small freshwater body. The changes of unpredictable nature are obviously due to the disturbances caused mainly by human activities, incoming surface runoff during rainy season and industrial wastes along with domestic pollution of which most of the fresh water bodies are exposed. Changes are felt much more quickly in the smaller bodies as compared to bigger and deep ones, which may take longer time to undergo such changes. The geo-chemical nature of rocks basin, sediments and seasonal changes which Rodhe (1949) considered to be of secondary importance for lakes attain prime importance in the case of these wetlands.

Sulphate (SO_4): The sulphate ion (SO_4) is usually second to carbonate as the principal anion in fresh waters (Cole, 1983). Free or elemental sulphur is inactive at ordinary temperature. This element combines with both metals and non-metal to form many compounds. The predominant form of dissolved sulphur in water is sulphate. Nearly, all assimilation of sulphur is as sulphate, but during decomposition of sulphur containing organic matter, sulphur is released largely as hydrogen sulphide (Wetzel, 1983). The most reduced state is sulphide (S^{--}), and the most important sulphides are the H_2S and FeS (Cole, 1983).

Relative contribution of sulphate compounds to natural waters varies with the regional lithology, agricultural application of sulphate-containing fertilizers and atmospheric sources (Wetzel, 1983). Entry of sulphate into fresh water systems is through a variety of sources such as rain water, sewage and also derived from sedimentary sources. With the increased industrialization, atmospheric sources of sulphates have also increased. Man now contributes about 2.4 times more SO_2 than the annual contribution from volcanoes (about 29 x 10^6 tons) to the atmospheric load of this gas .

It is a well know fact that autotrophic organisms and many heterotrophic bacteria require considerable quantity of sulphur from sulphate in the media. It is an important constituent of protoplasm and certain amino acids, like *cystine* and *methionine* having sulfhydryl (SH) bonding. This is a matter of considerable importance as regards the productivity of the water body.

Sulphates naturally occur in all kinds of natural waters. It is an important constituent of hardness with calcium and magnesium. Sulphate produces an *objectionable taste* at 300 to 400 mg/L. Above 500 mg/L, it has a *bitter taste* and at concentrations around 1000 mg/L, it acts as *laxative* (USEPA, 1990,1991). Natural waters contain few to several thousand-mg/L sulphate (APHA, 1992).

The concentrations of sulphate recorded during the period of study from all the three wetlands exhibited a peculiar trend (Table 9). At CP-1 and CP-2, it showed highest concentrations during summer months. In the case of M.P., higher concentration was recorded during the period of summer months as well as during October to December, 2001 (Table 9).

The high concentrations of sulphates recorded in the study during summer may be attributed to fast blowing hot and dry winds causing increased evaporation. Hutchinson (1957) also reported an increase in sulphate content in the enclosed water bodies of semi-arid regions during summer because of increased evaporation. Higher concentrate of sulphate recorded during monsoon and post-monsoon months (June to December, 2001) in MP, may be due to entry of rainwater, sewage and surface run-off from the surrounding agricultural catchment area. Rain water has quite high concentrations of sulphate particularly in the areas of high atmospheric pollution (Trivedy and Goel, 1984). Kumar (1995) has also reported high concentrations in these seasons correlating it with some organic matter deposited at the bottom of a wetland containing sulphur as sulphate or sulphide. During anaerobic condition, certain bacteria help in reducing sulphates into sulphides while certain colourless sulphur bacteria like *Beggiatoa* and *Thiobaccilus* are known to reduce H_2S in sulphides or SO_4 during aerobic oxidation (Odum,1971). Kannan (1991) reported higher values of sulphate during summer due to addition of sewage. The low values of sulphate in winter and other months were mainly found to be due to higher growth rate of phytoplankton and consequent utilization of sulphate (Pandey and Tripathi, 1988).

The recommended upper limit for sulphate ions in water for human consumption is 250 mg/L (Sawyer *et al.*, 1960). In the present study, it was never found more than the permissible limits (Table 9).

Table 9

Monthly variations in the concentrations of Calcium (mg/L), Magnesium (mg/L), Chloride (mg/L) and Sulphate (mg/L) in Wetlands.

Months ↓	Calcium (Ca)			Magnesium (Mg)			Chloride (Cl)			Sulphate (SO_4)		
Wetlands →	CP-1	CP-2	MP	CP-1	CP-2	MP	CP-1	CP-2	MP	CP-1	CP-2	MP
August, 2000	36.10	44.52	34.00	12.65	7.03	37.84	56.00	56.00	52.00	33.00	32.00	51.00
September	42.00	43.53	39.27	10.27	6.41	35.12	57.00	56.00	50.00	34.00	33.00	40.00
October	54.50	58.51	40.08	12.17	7.78	41.96	76.00	63.00	50.00	32.00	31.00	57.00
November	56.90	62.52	58.10	13.15	8.26	33.91	67.00	65.00	65.00	32.00	29.00	48.00
December	62.80	71.33	64.70	7.61	7.78	52.32	83.00	91.00	52.50	32.00	29.00	43.50
January, 2001	92.18	80.16	56.11	16.10	20.94	52.70	84.00	96.00	56.00	38.01	36.00	57.30
February	78.55	80.16	84.16	19.48	14.15	30.22	125.00	96.00	61.00	82.00	77.50	87.50
March	102.60	102.60	84.60	15.56	13.61	37.76	107.00	157.00	157.00	42.00	40.00	153.00
April	96.12	94.12	88.70	12.68	21.22	32.33	168.00	163.00	136.00	55.00	113.00	164.00
May	83.36	120.24	73.00	25.34	22.39	47.26	78.00	88.00	136.00	104.00	73.00	153.00
June	80.16	108.33	60.12	10.69	9.64	58.53	423.00	471.00	318.00	179.00	164.00	142.00
July	36.24	34.20	47.29	17.44	16.25	24.40	288.00	268.00	263.00	57.00	101.00	100.00
August	38.55	39.73	45.69	6.77	7.51	31.72	138.00	123.00	149.00	51.00	29.00	88.30
September	57.33	55.31	65.73	10.94	11.19	31.69	153.00	138.00	170.00	34.00	32.00	97.00
October	84.16	78.55	73.74	13.14	15.58	46.23	170.00	216.00	199.50	49.00	40.00	100.00
November	83.32	67.33	98.19	12.67	19.97	35.33	306.00	237.00	214.50	53.00	57.00	108.00
December	80.16	71.34	79.35	18.26	19.48	44.37	318.00	288.00	213.50	43.00	42.00	135.00

CP-1: Chharat Pond 1; CP-2: Chharat Pond 2; MP: Medical Pond

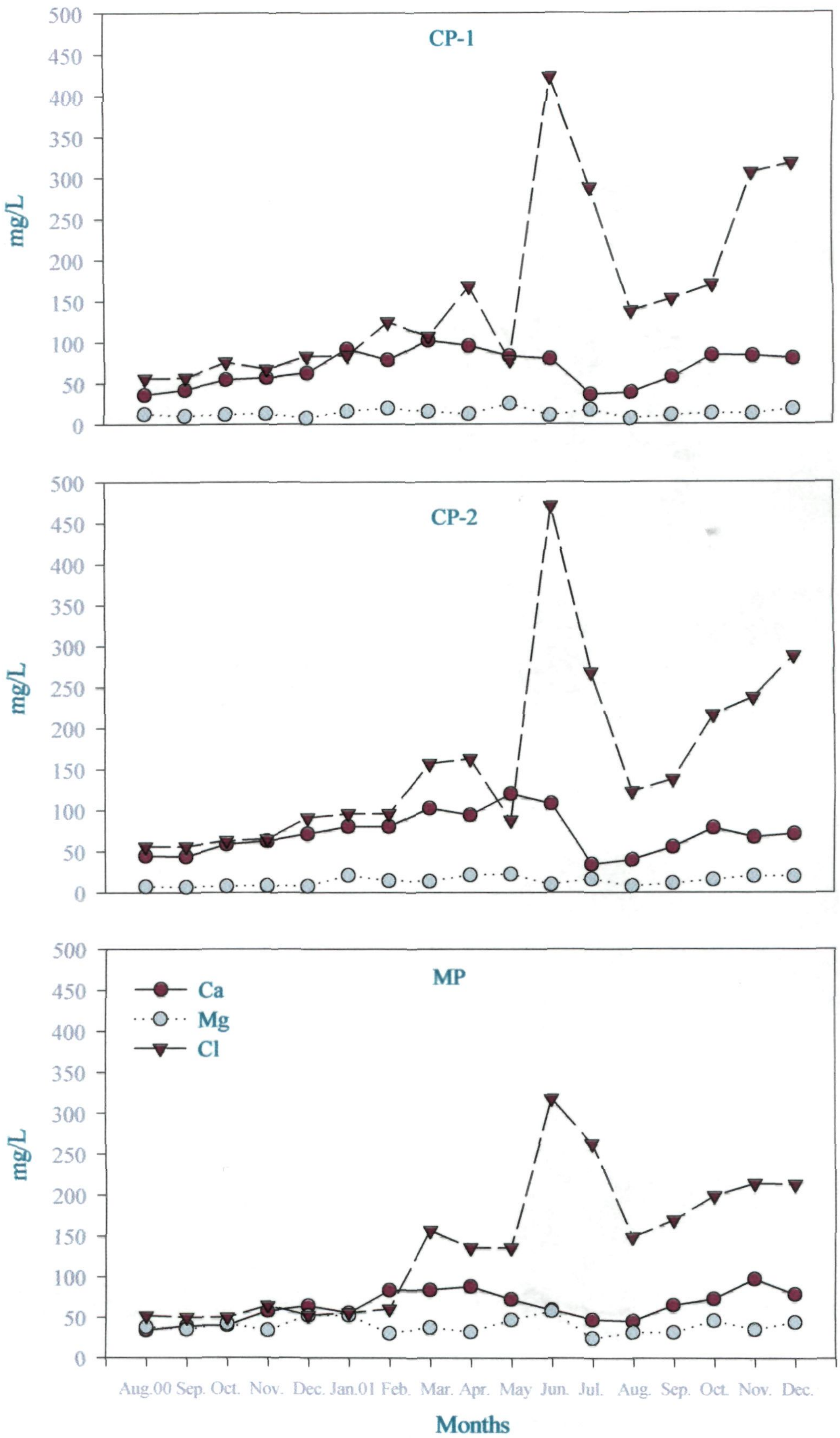

Fig. 6. Monthly variations in Calcium (Ca), Megnesium (Mg) and Chloride (Cl) at CP-1, CP-2 and MP Wetlands.

(v) – DISSOLVED NUTRIENTS OF THE WETLANDS

Nutrients have been, and continue to be, targeted for research and management in the Bays, rivers and wetlands. Such researches have largely focused on the inputs of these nutrients from external sources, such as river flow, sewage, subterranean water and surface run-off, as these are considered to be the entities for planktonic growth (Bronk *et al.*, 1998). The load of nutrients to aquatic systems has greatly increased with time through human activities (Conley, 2000). The concentration of dissolved substances in water plays a very important role in the metabolism of various groups of aquatic organisms. Some of these dissolved substances are known to be of great importance as both macro- and micro- nutrients. The distribution of these nutrients is not uniform in different wetlands as they undergo cyclic changes during which there are periods of delay between the available mineralized state and unavailable bond state (Kemp and Dodds, 2001).

Although a wide variety of mineral and trace elements can be classified as nutrients, but those required most by aquatic flora and fauna are Carbon (C), Nitrogen (N) Phosphorous (P), Silicates (Si), Ammonia-Nitrogen (NH_3-N), Nitrate-Nitrogen (NO_3-N), Nitrite-Nitrogen (NO_2-N) etc. Out of these, some are required in abundance while others are required in traces by aquatic flora and fauna.

Eutrophication of most fresh waters including wetlands is dependent upon supplies of nutrients like nitrogen and phosphorus (Vollenweider, 1968). In the case of freshwater bodies, a strong quantitative framework has been developed, over the past three decades that allows the prediction of algae biomass and other water quality parameters from nutrient loading and water column nutrient concentrations. These tools are employed with great success in water quality management of lakes world wide (OECD, 1982; Smith, 1982; Canfield, 1983; Reckhow and Chapra, 1983; Ryding and Rast, 1989 ; Sas, 1989; Cooke *et al.*, 1993).

The study of all these nutrients is of paramount importance for the proper management of the wetland ecosystem. Therefore, a through knowledge of the important nutrients and their effect on the productivity of the wetland is necessary.

The wetlands under investigations receive their nutrient supply from outside source (*allogenic*) as well as from the body of water itself (*autogenic*). Allogenic nutrients are brought in these wetlands by human activities, like agricultural runoff during rainy season sewage discharge, ground water inputs and atmospheric rains, while autogenic nutrients are produced as a result of synthesis of inorganic substances through decomposition of organic matter of plants and animal tissues.

It is widely accepted that increase in nutrient loading have taken place from anthropogenic activities, however the magnitude of that increase in poorly known (Conley, 2000). As a consequence of this increased nutrient loading, detrimental effects have been observed on the health of aquatic ecosystem leading to, amongst other things, excess accumulations of phytoplankton biomass (Malone *et al.*, 1986), episodes of noxious blooms, reduction in aquatic macrophytes communities (Sand-Jensen and Borum, 1991; Duarte, 1995) and depletion of dissolved oxygen in bottom waters (Malone *et al.*, 1996)- the condition called as eutrophication.

The importance of nutrients such as nitrogen, phosphorus, silicates and ammonia-nitrogen has long been recognized and their action on the biological activities of the ponds, lakes and wetlands have been discussed in detail by Lewis (1954), Gerloff and Skoog (1957), Ruttner (1963), Vaccaro (1965), Zafar (1967), Hynes and Grieb (1970), Ryther and Dunstan (1971), Khan and Siddiqui (1974), Hitchinson (1975), Zutshi and Vass (1978),Chourasia and Adoni (1985), Singhal *et al.* (1986), Schindler (1987), Hecky and Kilham (1988), Henriksen and Brakke (1988), Kaushik *et al.* (1989, 1990, 1991), Sarkar (1989), Kant and Raina (1990), Prasad (1990), Molot and Dillon (1991), Egge and Aksnes (1992), Conley *et al.*, (1993), Rigler and Peters (1995), Malone *et al.* (1996), Dodds *et al.* (1996, 1998), Dodds (1997), Dodds *et al.* (1997), Khan *et al.* (1999, 2002), Keddy and Fraser (2000), Dodds and Welch (2000), Biggs (2000), Mc Laughlin and Bindle (2001), Czernas (2001), Kemp and Dodds (2001), Babu *et al.* (2001), Kaushal *et al.* (2001). Gaur *et al.* (2002), Kumar (2002) and Hosetti (2002).

METHODOLOGY

For the analysis of nutrients, samples were collected from the three wetlands of Aligarh region for seventeen months at regular intervals and at fixed time. Analysis was completed within 24 hours from the time of collection, following necessary precautions and procedures laid down by Barnes (1959), Trivedy and Goel (1984) and APHA (1992).

***Inorganic Phosphorous* (*PO4-P*)** was estimated by the ammonium molybdate blue method using stannous chloride ($SnCl_2$) as an indicator (Barnes, 1959).

***Ammonia-Nitrogen* (NH_3-*N*)** was estimated by the nesselerization method as given by Barnes (1959).

***Nitrate-Nitrogen* (NO_3-*N*)** was determined following the phenoldisulfonic acid method given by Theroux *et al.* (1943) and Trivedy and Goel (1984)

***Nitrite-Nitrogen* (NO_2-*N*)** present in the surface water of the wetlands was estimated following the methods given by Trivedy and Goel (1984).

Silica content of the waters in these wetlands was estimated by the ammonium molybedate yellow method (Barnes, 1959).

All the results were obtained in mg/L except NH_3-*N* which was determined in μg atom /L

RESULTS AND DISCUSSION

***Inorganic Phosphorus* (PO_4-*P*)**:In the present investigations, inorganic phosphorous contents showed wide variations in all the three wetlands as given in Table 11 and shown in Fig. 7.

In CP-1, it ranged from 0.191 (December 2001) to 1.090mg/L (June 2001) and in CP-2 the range was between 0.198 (December 2001) to 1.190 mg/L (June 2001), whereas in MP, it fluctuated from 0.359 (August 2001) to 1.425 mg/L (May, 2001).

Phosphorus is a primary nutrient for aquatic plant growth and is a major cause of eutrophication in rivers, lakes, ponds and streams (McLaughlin and Brindle 2001). It is absolutely necessary to all life mainly for the storage and transfer of cell's energy and in genetic systems (Cole, 1983).

Shallow waterbodies have a good sunlight penetration and oxygen exchange to the bed, which allows for continued microbial action as well as photosynthetic waste utilization. It was the photosynthetic removal of phosphates that led to the concept of using shallow waterbodies for nutrient removal (McLaughlin and Brindle, 2001).

When phosphorus enters into the water body, it is passed through various physical chemical and biological phases involved in phosphorous cycle (Hutchinson, 1975 b). It is believed to be a critical limiting factor for biological productivity (Welch, 1952; Hutchinson, 1967; Goldman and Horne, 1983). This element occurs in combination with some anions like iron (Fe) and Calcium (Ca). It occurs in surface waters in three forms: i) *the inorganic or soluble phosphate-phosphorous* (*PO_4-P*), *ii*) *the soluble organic phosphorous iii*) *the particulate organic phosphorous.*

In the present study, the inorganic phosphate-phosphorous, showed seasonal variations in all the three wetlands under investigation (Table11 and Fig.7). A very peculiar trend was noted in the seasonal/monthly variations of PO_4-P in CP-1 and CP-2 .It showed quite good concentrations during August, 2000 to February 2001. It's concentration reach to maximum during summer of 2001 (March- June 2001), then it gradually started decline during rest of the investigating period showing minimum concentration in December 2001. In MP, it was found to be higher during September, 2000 and summer of 2001 showing maximum concentration in May 2001.

Increased values during summer were mainly due to regeneration of inorganic phosphorus from the organic form during decomposition. During summer seasons the highest content of PO_4-P was also related to hot wind blowing with speed, decrease in water level due to raised temperature and, thereby, higher evaporation rate. Higher release of inorganic P in water at high temperature may also be attributed to high turnover rates and decomposition of large plant population in addition to wind recycling (Chourasia and Adoni, 1985; Singhal *et al.,* 1986; Kaushik *et al.*, 1991a; Prasad, 1990 and Kant and Raina, 1990).

Sarkar (1989) has reported that percentage and rate of P release is also regulated by the interaction of nutrients, soil texture, abiotic and biotic factors, pollution potential and biological activity.

It is quite likely that the circulation of inorganic PO_4-P in these wetlands was a major cause of algal bloom during summer. Similar algal blooms caused by nutrients enrichment of waterbodies have been reported by Hasler (1947), Anderson (1960), George (1962) and Khan and Siddiqui (1974).

Lower phosphate level during winter season may be due to its utilization in macrophytic growth and its sedimentation in the form of ferric complexes in soil due to low calcium level in the water and low water temperature (Seenayya, 1971; Khan and Siddiqui, 1974; Sarkar, 1989; Kaushik *et al.*, 1989, 1990). In the present study too, low values were obtained in wetlands CP-1 and CP-2 during winter, 2001 (Table11). However, Zutshi and Vass (1978) have reported high phosphorous content in winter season. Low values during monsoon months (August-September, 2001) might be due to dilution of water through falling rainwater.

The phosphate-phosphorus content more than 2 mg/L in open waters gives a sign of organic pollution (Pomeroy *et al.,* 1965). In all the three wetlands, under investigations, phosphorus was never found above this limit, indicating clearly its high trophic status. Having high trophic status, these wetlands can be used for aquaculture practices.

When analysed statically, a direct correlation was obtained between PO_4-P and phytoplankton (Fig. 17) at CP-1 ($r = 0.317$, $p<0.05$); CP-2 ($r = 0.351$, $p<0.05$) and MP ($r = 0.462$, $p<0.05$). On the other hand, it showed significant relationship with zooplankton (Fig. 18) at CP1 (r = -0.0.550, $p<0.05$); CP-2 ($r = -0.550$, $p < 0.05$) and direct at MP ($r = 0.423$, $p < 0.05$). Khan and Siddiqui (1974) have reported significant inverse relationship between phytoplankton and phosphorus concentration, while Trivedy *et al.* (1985) have reported positive relationship between inorganic phosphorous and plankton density.

Nitrogenous Compounds: Nitrogen is the main component of protein, short-chain peptides and acids, which, in turn, are the principal components of artificial and natural feeds used in aquaculture (Mohanty, 2000). Wetlands are still ecosystems with closed basins. These wetlands are strongly influenced by inputs of nutrients from the terrestrial watershed in which they lie. According to Likens and Bormann (1972), nutrients in lentic systems originate from biological, geological and meteorological pathways. Nitrogen in the aquatic environment is derived primarily from sources other than atmospheric nitrogen. It is formed when complex organic matter is broken down into simple forms by bacterial decomposition. Proteins for instance, are converted into amino acids and further reduced into ammonia-nitrogen (NH_3-N). If O_2 is present, (NH_3) is oxidized to nitrite (NO_2^-) and then to nitrate (NO_3^-) with the help of certain nitrifying bacteria (*nitrosomonas* and *nitrobacter*). The nitrate can then be reconstituted into living organic matter through utilization by photosynthetic plants (WHO, 1984). The other sources of nitrogen in a wetland include animal wastes, chemicals fertilizers, wastewater discharge, sewage run-off etc. Ground water contamination by nitrogen from fertilizers and animal wastes has been a fairly high profile issue for a number of years, particularly in Northern Europe and also in other countries where intensive agriculture and animal husbandry are practiced. This has been mainly out of concern about nitrate levels in drinking water but in wetlands it leads to eutrophication (CEEP-2001).

In the present study of these three wetlands at Aligarh, three forms of soluble inorganic nitrogen, were studied and investigated. They are Nitrate-Nitrogen, Nitrite-Nitrogen and Ammonia-Nitrogen. Wide fluctuations were recorded in NO_3-N, NO_2-N and NH_3-N. Seasonal variations, observed during the course of study, are given in Table10 and Fig. 8.

Nitrate-Nitrogen (NO_3-N): The amount of NO_3-N in CP-1 ranged from 0.052 to 0.240 mg/L. Maximum was recorded in the month of November, 2001 and minimum in the month of December, 2000. In CP-2 it was found to vary from 0.050 to 0.237 mg/L showing maximum and minimum values in November, 2000 and December, 2000 respectively. Both the ponds follow the same trend of fluctuations (Table 10). MP showed fluctuation of NO_3-N, from 0.081 to 0.278 mg/L. The maxim was recorded in the month of November 2001, and minimum in September-October, 2000 i.e. slightly different from that of CP-1 and CP-2.

Higher concentrations of NO_3-N were found during post-monsoon of 2000 and summer, monsoon and post monsoon months of 2001 at CP-1 and CP-2, whereas low values were recorded during November to December, 2000. In the case of MP, NO_3-N values were found to be minimum during September to October, 2000 then the values showed increase and decrease till August 2001, after that the values increased greatly reaching to its maximum during November 2001.

Nitrate-Nitrogen is the main source of nitrogen and regarded as an important nutrient used in the maintenance of proteins and productivity of water. Among nitrogenous compounds, NO_3-N is considered to be one of the most important limiting factors in the development of phytoplankton and is a nutritive substance necessary for the production of chlorophyll (Welch, 1952; Wetzel, 1975; Goldman and Horne, 1983 ; Kumar,1997).

The NO_3-N, content showed wide seasonal fluctuations (Table10). Almost all the wetlands under study showed higher concentrations of NO_3-N during monsoon and post monsoon months indicating that these wetlands receive their nitrogen supply through drainage, catchment area and surface runoff. The presence of nitrogenous compounds in rain water is well known, though their origin is by no means as well established as in commonly believed (Hutchinson, 1975).

Nitrate-Nitrogen moves rapidly through the soil with drainage water and is influenced by biological factors. In the present study, a negative correlation was obtained (Fig. 19) between NO_3-N and phytoplankton ($r = -0.241$, $p<0.05$; $r = -0.252$, $p<0.05$; $r = -0.349$, $p<0.05$ at CP-1, CP-2 and M.P respectively). Haque (1991) found significant and positive correlation between phytoplankton and NO_3-N. In the present investigations, inverse correlation might be due to lowering of NO_3-N because of its utilization by increased phytoplankton and other macrophytes population for their growth and reproduction. Sarwar (1999) have also reported negative correlation between these two variables. Further, it has been observed that high concentration of NO_3-N was associated with a high concentration of PO_4-P. Therefore, significance of NO_3-N in the production of phytoplankton cannot be determined separately. Moyle (1949) reported that hard water ponds with a total phosphorous content above 0.05mg/L and with a total nitrogen content below 0.5 mg/L yielded less than the ponds with a higher nitrogen contents, although NO_3-N is only occasionally a limiting factor in the productivity. Contrary to these observation, PO_4-P values were always found greater than NO_3-N values with relatively good production in all the three wetlands (Table10 and 11).

Nitrite- Nitrogen ***(NO_2-N)***: Nitrites occur in fairly good amounts. In the present study, levels of NO_2-N ranged from 0.070 to 0.491 mg/L at CP-1, being maximum in the month of August, 2001 and minimum in the month of March, 2001.In CP-2, it ranged from 0.049 to 0.580 mg/L, being maximum in the month of August 2001 and minimum during June, 2001.In case of M.P, NO_2-N varied from 0.018 to 0.471 mg/L, the maximum was recorded in the month of July, 2001 and minimum value in November, 2000 (Table10).

Nitrites are not stable end products and their absence or presence in small quantities may not owe much significance. The concentration of nitrites in the water depends on the relative abundance of nitrifying and denitrifying organisms and their activities.

In the present study, NO_2-N showed wide seasonal fluctuations (Table10). Higher values were found during winter, monsoon and post-monsoon months at CP-1 and CP-2. The rest of the months showed low values with very little variations in the NO_2-N concentrations.

In the case of M.P, very low values of NO_2-N were recorded during post monsoon months of 2000 (September-October.2000). Thereafter, it increased and showed consistency in almost all the remaining months of investigations (Table10).

The presence of appreciable amount of NO_2-N in these wetlands has been due to sewage contamination, use of fertilizers in the adjoining fields and catchments area, decaying vegetables, animal waste matter, municipal wastes and discharge from automobile exhausts enter through atmospheric wash out during rainy season. The high values in monsoon may be due to entry of surface run-off water from the surrounding agriculture fields, whereas lower concentration of NO_2-N may be due to low water temperature, higher dissolved oxygen content, less deposition of organic matter and greater sedimentation rate (Kaushik and Saksena, 1999). Further, low values of No_2-N during March, 2001 may be attributed to the factors like utilization by green aquatic organisms as a nitrogen source (Wetzel, 1975), and its conversion into NO_3-N by the action of certain nitrifying bacteria (eg. *Nitrosomonas*). Statistical analysis showed negative correlation between phytoplankton density and NO_2-N at CP-1 and CP-2 ($r = -0.099$, $P<0.05$ at CP-1;($r = -0.195$, $P<0.05$ at CP-2), whereas in the case of M.P, it was found to be positive correlation ($r = 0.445$, $p<0.05$) (Table19).

Further, in the present study, it was observed that the high nitrite content promoted a mixed bloom of various algal species dominated by blue-green algae and diatoms during summer and monsoon months. The gradual decrease in later months was probably due to consumption by the same mixed algal bloom dominated by *Cyclotella, Naviculla* and other diatoms (Plate 4). Bharati and Hosmani (1975) have also attributed low levels of NO_2-N due to utilization by phytoplankton.

Ammonia-Nitrogen ***(NH_3-N)***: The NH_3-N concentrations of all the three wetlands during different months of the study are shown in Table 10. In CP-1, it ranged from 31.09 to 101.0 µg atom/L. The highest value was recorded in the month of July, 2001 and lowest in the month of December, 2000 (Table 10). In case of CP-2 it varies from 13.05 to 95.00µg atom/L, showing highest value in November,2001 and lowest in February, 2001. While in case of MP the values fluctuates from 52.5 to 113.5µg atom/L, the maximum value was recorded in the month of January and April, 2001 and minimum in the month of September, 2000.

It provides a source of recycled nitrogen for speedy growth of phytoplankton and macrophytes when other forms of nitrogen are exhausted (Goldman and Horne, 1983). It is found in a water body mainly as a result of ammonification of organic nitrogen through decay causing ammonifying bacteria. Considerable amount of NH_3 produced during the decomposition of planktonic organism, may be liberated by direct bacterial action or without the formation of soluble intermediate products (Von Brand and Rakestraw, 1940). It is also produced by the bacterial reductions of Nitrate (Hutchinson, 1975). It is always found in small quantities in aquatic environment as it is one of the excretory products of aquatic animals. Fishes are known to excrete sufficient amount of ammonia to stimulate aquatic plant metabolism (Goldman and Horne, 1983).

In the present study, ammonia -nitrogen has been found to be present in all the samples collected from the three wetlands. The fluctuations exhibit a trend of increased values of NH_4-N in the monsoon and post monsoon months at CP-1 and CP-2. Rest of the months show less concentrations of NH_4-N (Table10). In the case of

M.P, NH_3-N showed higher concentration during December, 2000 to February, 2001, April to June, 2001 and August, 2001. The rest of the months showed almost similar values for NH_3-N (Table10).

The higher concentrations of ammonia-nitrogen during summer, monsoon, and post-monsoon months in these wetlands might be due to decaying organic matter and high temperature which increases ammonification more rapidly than assimilation (Rao and Govind 1964; Ayyapan and Gupta 1981a, b, c; Kanabur, 1990; Haque 1991; Paul and Verma 1999). The considerable high amount in these months may also be due to inflow of decaying organic matter through drainage nullah and surface run-off.

During winter the rise in the concentration of NH_3-N in these wetlands may be attributed to the release of nitrogen from soil colloids, decomposition of organic matter and the conversion of insoluble to soluble salts that appears to have contributed to rise in values to a lesser extent as compared to rain washings. Such releases are possibly the major contributory factors for sudden rise of NH_3-N enriching these ponds during winter as reported by Pennak (1949), Hutchinson (1975) and Haque (1991).

The decrease in the concentrations of NH_3-N appears to be due to utilization by phytoplankton and other green aquatic plants during various months of the study as ammonia-nitrogen has been reported to be preferred form of nitrogen for plant growth than other forms of nitrogen (Goldman and Horne, 1983). Earlier, Toetz (1971) also reported decrease in ammonia-nitrogen in a water body due to rapid utilization by macrophytes and periphytic communities.

When statistically analysed, it was found that NH_3-N and phytoplankton showed a negative correlation at CP-1 and CP-2, and positive at MP (Table19).

Such variation in the relationship between NH_3-N and Phytoplankton seems to be due to release of NH_3-N by aquatic animals excretory wastes, bacterial decomposition and utilization by green aquatic organisms including phytoplankton, perphyton and macrophytes, as actual amount, of ammonia present at any time depends upon the balance between plant uptake and bacterial oxidation (Goldman and Horne, 1983).

According to Ellis *et al.* (1964) unmodified natural waters contain very little amount of ammonia and ammonium compounds (less than 0.1mg/L). Reid (1961) has reported that these substances when present in quantities more than 1.0mg/L are indicative of organic pollution. In the present wetlands, the values of NH_4-N were found to be much lower than those reported for unmodified natural waters by Ellis *et al.* (1964).

Silica –Silicates: Silica is the second most abundant element in the lithosphere (Cole, 1983). It does not occur in the nature as a free element. Natural waters commonly contain silicon dioxide in some form of soluble silicates. It also occurs in colloidal form, particularly in riverine environment (Welch, 1952). Wetzel (1983) reported that silica occurs in fresh waters in two major forms :

(i) *Dissolved silicic acids form stable solution of H_4Sio_4 at much higher concentrations than are encountered in fresh waters.*

(ii) *Particulate silica which is formed in two forms – that in biotic material, particularly in diatoms and few other organisms that use the large amount of silica, and that adsorbed to inorganic particles or complex organically.*

Its main source in fresh waters is weathering of the extremely abundant feldspar rocks (Cole 1983). It is also produced during degradation of alminosilicate minerals (Wetzel, 1983 and Kaushik and Saksena, 1999). Greatest concentrations of silica are found in ground waters in contact with volcanic rocks. Intermediate amounts occur in association with pulotonic rocks and sediments containing feldspar and volcanic rock fragments. Small amounts may originate from marine sand stones (Wetzel, 1983).

In Inland waters, it ranges from 0.1 to 4000 mg/ L, representing the extremes from snow melt to hot mineral springs. The silica content of river waters tends to be remarkably uniform and shows little response to changes in discharge rates (Edwards and Liss, 1973). In rivers and lakes, it ranges from 2 to 25 mg/L and is usually expressed as silicon dioxide (SiO_2) in water analysis (Cole, 1983). The world average is about 13mg /L in natural water bodies (Davis, 1964).

Silica is an essential nutrient for diatoms, which build their frustules of this glassy material. Silica in the form of orthosilicic acid is also known to be an essential macronutrient for the growth of diatoms. It is reported that autotrophic and many heterotropic organisms require silica for their normal growth (Paul and Verma, 1999).

It is also reported to be essential for the growth of many planktonic *chrysophyceans* organisms for the construction of their silicified scales and spores (Cole, 1983, Wetzel, 1983). Several more recent studies have examined the role of dissolved silica in regulating phytoplankton composition and its impacts on diatoms in food web dynamic (Doering *et al.,* 1989; Dorth *et al.,* 1992; Egge and Aksnes, 1992). Among other freshwater animals, the main users are freshwater sponges which build their glassy spicules with silica (Welch, 1952). In addition certain aquatic macrophytes (*Equisetum*) are also known to utilize silica for their development and growth (Wetzel, 1983)

The concentration of the silicates recorded during the period of study from all the three wetlands were found to show wide variations (Table11). It ranged between 0.0137 to 0.1887 mg/L, 0.0137 to 0.1162 mg/L and 0.0218 to 0.1912 mg/L in CP-1, CP-2 and M.P respectively (Fig. 7). Since diatoms require silicon for their shells and since they constitute a very prominent and strategic group in plankton at large, the available supply of silicon in water is regarded as a matter of real consequence. Large growths of diatoms draw heavily upon the silicon crop, producing variations in it in the upper waters (Welch, 1952). In fact, it is claimed that the production of diatoms is directly determined by the silicon supply.

The Si fluctuations exhibit a general trend of increase in monsoon, post monsoon & winter months at CP-1 and CP-2, whereas in the case of MP, it showed higher values in winter (2000 and 2001) summer, monsoon and post-monsoon months of 2001 (Table11).

Higher concentrations of silicates during monsoon and post-monsoon periods at CP-1 and CP-2 may be due to incoming drainage and surface run-off which react upon with CO_2 to produce silica as also reported by Hutchinson (1975). Conley *et al.* (1993) also suggested that increase in Si might be due to anthropogenic activities.

Increase in Si concentrations at MP during summer may be due to evaporation of water. Further, higher values during summer may also be due to release of silica during decomposition of organic matter at higher temperature as also suggested by Khan and Siddiqui (1974), Ramanibai and Ravichandran (1987) and Mohan (1987). The release of dissolved silicate from the regeneration of diatom frustules is also a temperature dependent process with the highest concentration of dissolved silicates often observed in estuaries during the summer (Conley and Malone, 1992).

In the present investigations, all the three wetlands showed irregularity in the silica content as it was found to decrease during different month of the study. It may be due to utilization by phytoplankton specially diatoms and macrophytes present in the water bodies and less release during suppressed decomposition activity at low water temperature and sedimentation. Similar observations were also made by Ganapati (1956). Considerable information is available on the Si content and its utilization by diatoms and other algae in the surface waters from various workers (Hutchinson, 1967; Schelske and Stoermer, 1972, 1972a; Cole, 1983; Saksena *et al.*, 1986; Yousuf *et al.*, 1986; Kumar, 1995; Narender and Mehmood, 1995; Sabu and Abdul, 1996).

In the present investigations, silica values showed inverse relationship with diatoms at CP-1 and CP-2 and positive at MP (Table 19). Lund (1965) also reported an inverse relationship between diatom crop and soluble silica in a freshwater body. Some diatoms blooms have been reported to reduce silica concentration to deficiency levels (Munawar, 1974).

Hutchinson (1975) gave detailed account of the silica content in surface waters of several freshwater lakes of Europe, Japan and America. These data suggest that greater Silica concentrations occur in tropical waters than in temperate waters as found here in these wetlands.

Table 10

Monthly variations in Nitrate-Nitrogen (mg/L), Nitrite-Nitrogen (mg/L) and Ammonia-Nitrogen (µg atom/L) in Wetlands.

Months ↓ Wetlands →	Nitrate-Nitrogen (NO_3-N)			Nitrite-Nitrogen (NO_2-N)			Ammonia-Nitrogen (NH_3-N)		
	CP-1	**CP-2**	**MP**	**CP-1**	**CP-2**	**MP**	**CP-1**	**CP-2**	**MP**
August, 2000	0.117	0.124	0.157	0.204	0.247	0.298	58.27	53.66	79.25
September	0.087	0.081	0.081	0.151	0.114	0.077	61.00	59.00	52.50
October	0.112	0.118	0.081	0.271	0.261	0.057	74.00	66.09	72.50
November	0.056	0.057	0.134	0.150	0.141	0.018	46.09	44.08	71.50
December	0.052	0.050	0.182	0.114	0.161	0.310	31.09	36.01	84.50
January, 2001	0.092	0.088	0.122	0.305	0.291	0.351	54.09	51.05	113.50
February	0.071	0.081	0.146	0.215	0.270	0.307	31.90	13.05	84.50
March	0.156	0.115	0.117	0.070	0.130	0.430	34.00	34.05	71.50
April	0.117	0.113	0.123	0.160	0.149	0.379	43.05	27.05	113.50
May	0.086	0.096	0.161	0.114	0.080	0.330	64.00	47.00	108.00
June	0.081	0.123	0.151	0.102	0.049	0.310	85.00	81.05	98.50
July	0.161	0.153	0.195	0.370	0.550	0.471	101.00	94.00	68.50
August	0.131	0.141	0.131	0.491	0.580	0.470	64.05	37.07	109.50
September	0.175	0.163	0.267	0.102	0.220	0.231	39.92	27.09	68.50
October	0.170	0.151	0.179	0.398	0.221	0.330	76.09	88.00	60.00
November	0.240	0.237	0.278	0.160	0.121	0.325	70.09	95.00	76.00
December	0.086	0.163	0.176	0.105	0.171	0.379	57.05	59.05	75.00

CP-1: Chharat Pond 1; CP-2: Chharat Pond 2; MP: Medical Pond

Table 11
Monthly variations in Phosphate-Phosphorus (mg/L) and Silica-Silicate (mg/L) in Wetlands.

Months ↓ Wetlands →	Phosphate-Phosphorus (PO_4-P)			Silica-Silicate SiO_2		
	CP-1	**CP-2**	**MP**	**CP-1**	**CP-2**	**MP**
August, 2000	0.635	0.717	0.586	0.0950	0.0900	0.0450
September	0.785	0.761	1.040	0.1887	0.1025	0.0387
October	0.541	0.570	0.586	0.0825	0.0787	0.0450
November	0.570	0.584	0.586	0.0887	0.0825	0.0460
December	0.707	0.635	0.419	0.0825	0.0862	0.1031
January, 2001	0.550	0.510	0.620	0.0137	0.0150	0.1587
February	0.695	0.586	0.695	0.0150	0.0137	0.0225
March	0.761	0.867	0.761	0.0825	0.0687	0.0218
April	0.965	0.950	0.812	0.0425	0.0317	0.1912
May	0.941	0.919	1.425	0.0475	0.0865	0.1862
June	1.090	1.190	0.867	0.1887	0.0212	0.1887
July	0.586	0.549	0.470	0.0925	0.0975	0.0975
August	0.321	0.420	0.359	0.1350	0.0950	0.0725
September	0.234	0.289	0.390	0.0762	0.0462	0.0837
October	0.290	0.287	0.490	0.1187	0.1075	0.1662
November	0.226	0.240	0.460	0.1012	0.1162	0.1775
December	0.191	0.198	0.656	0.0637	0.0587	0.1887

CP-1: Chharat Pond 1; CP-2: Chharat Pond 2; MP: Medical Pond

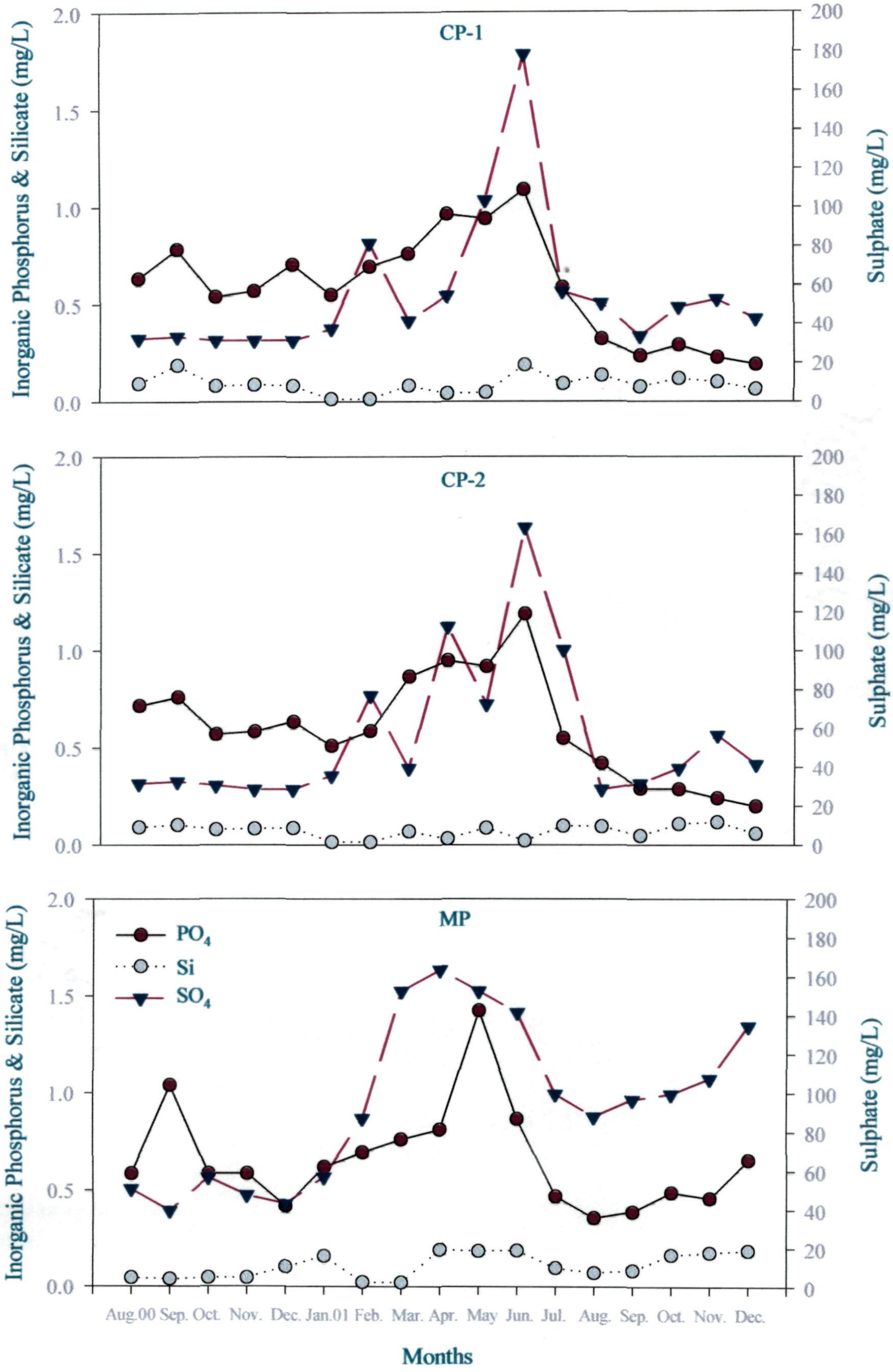

Fig. 7. Monthly variation in Inorganic Phosphate-Phosphorus (PO_4-P), Silicate (SiO_2) and Sulphate (SO_4) at CP-1, CP-2 and MP Wetlands.

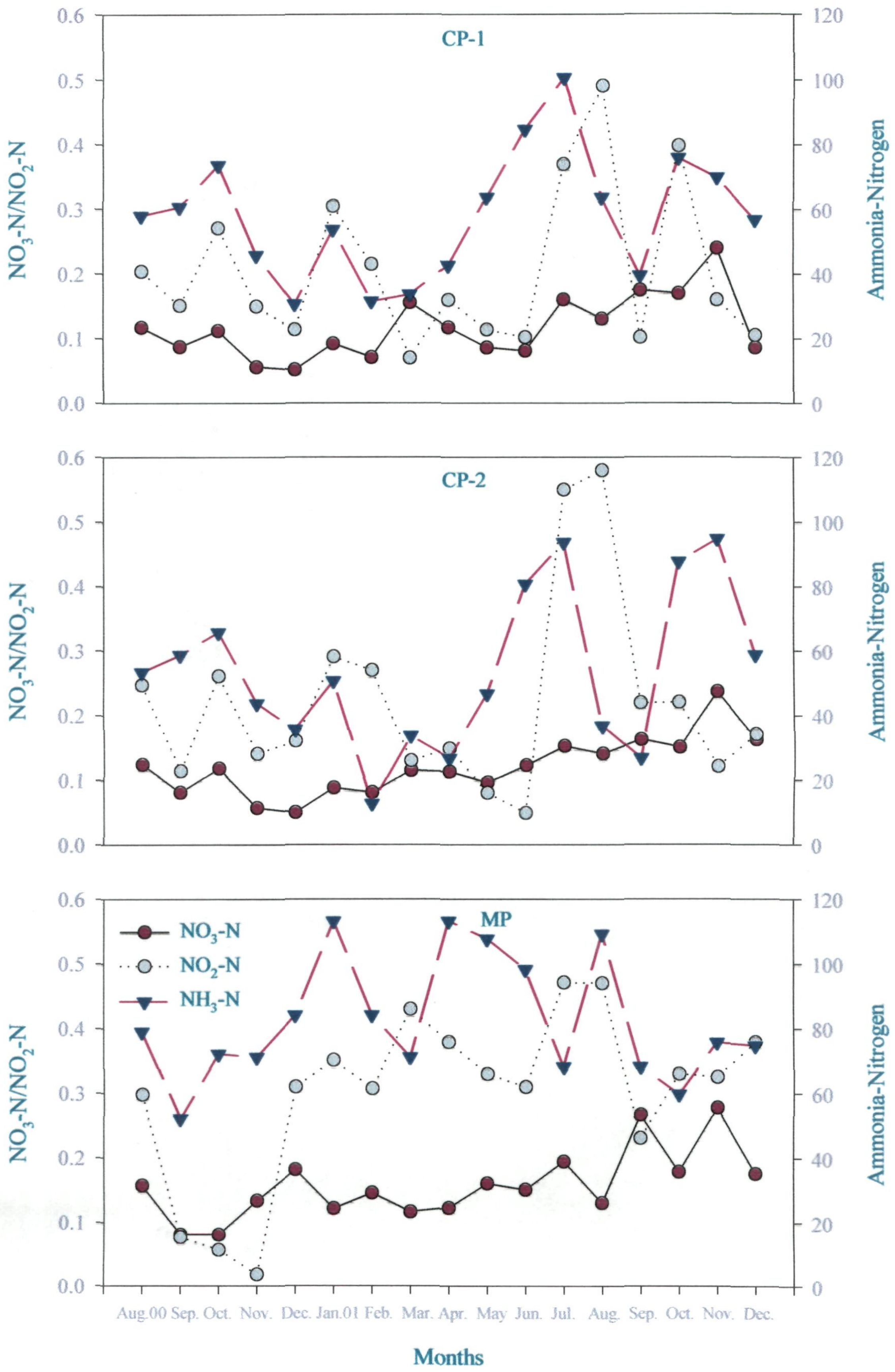

Fig. 8. Monthly variations in Nitrate-Nitrogen (mg/L), Nitrite-Nitrogen (mg/L) and Ammonia-Nitrogen (μg atom/L) at CP-1, CP-2 and MP Wetlands.

Chapter V

LIMNOBIOLOGY

(i) – PLANKTON

Biological communities in general and plankton communities in particular are not haphazard aggregations of the species thrown together by the whims of nature, but rather structured communities with numerous interlocking cause-effect pathways. It is evident that the requirement of biological species and communities is nearly as complex as those of taxonomically higher organisms and that disruption of these communities by pollution can affects the entire aquatic food web (Unni, 1993, Pai, 2002).

In recent years, there is a wide spread recognition that chemical monitoring alone is not enough. Pollution brings many biological changes and its impact is on living organisms. Hence, chemical and biological approaches are complementary and it is appropriate to detect and assess impacts through an examination of the biota.

Biological studies are of great importance and have several advantages over chemical studies. A skilled biologist is able to predict the quality of water in few minutes but a chemist or a sanitary engineer has to wait for days, for the determination of biological oxygen demand (Sladecek, 1979). To quote Cairns and Pratt (1993) "*Biological surveillance of communities, with special emphasis on characterizing taxonomic richness and composition, is perhaps the most sensitive tool now available for quickly and accurately detecting alterations in the aquatic ecosystem*".

Plankton communities respond to intermittent pollution, which may be missed in chemical sampling programs. A biologist, however, sampling at monthly intervals, alongside the chemist, will record an unexpected depression in the diversity of the biological communities, as some species may be eliminated or killed by the pollutants. Some of the species missing are known to be especially sensitive to certain chemical parameters and act as biological indicators (Sinha, 2001).

The advantages of biological methods however do not eliminate the need for chemical analysis of water samples. Agencies and individuals responsible for establishing assessment programmes must integrate both methods to provide a system which is not too expensive and which provides the necessary information with maximum efficiency (Sinha, 2001).

Most of the plankton are used as biological indicators or bio-indicators in biomonitoring programmes which have been of particular interest to the *International Union of Biological Sciences* (*IUBS*), who at 21st General Assembly in 1982, initiated '*The bio-indicators programme*' in Ottawa and recommended to organize biological monitoring programmes. The General Assembly advocated the role of biological indicators in monitoring by way of the following:

(i) Encourage scientific and national bodies to develop and improve methods for monitoring environmental changes. (ii) Promote interdisciplinary and international cooperation in standardizing methods. (iii) Encourage the exchange of research results amongst laboratories of the world. (iv) Support conferences dealing with bio-indicators at cellular, individual, population and ecosystem level (Sinha, 2001).

During the present investigations in these wetlands an attempt was made to study various plankton, fishes and other aquatic organisms inhabiting in them. The *plankton* community is a heterogeneous group of tiny plants (*phytoplankton*) and animals (*zooplankton*) adapted to suspension in any water body. Their intrinsic movements, if any, are so feeble that they remain essentially at the mercy of water movements. According to Oceanographer, Victor Hensen, who first proposed the term "*plankton*" in 1887 for the "*heterogeneous assemblage of minute organisms and finely devided non-living material then known to occur in the sea and to float about at the will of the waves and other water movements*". (Welch, 1952 and Battish, 1992).

Ecological study on plankton of any water body is a prerequisite to know about the general economy and to understand the basic nature of the water body (Singh 1990; Birsal, 1996 and Gopal, 1999).

Ever since the early days of plankton research, increasing number of international expeditions of various nations under certainties with regard to efficiency and selectivity of the various types of plankton gear, has called for paying more and more attention to this field of biology (Anonymous, 1975).

Since plankton serve as a food for economically important culturable fish species and their fry and fingerlings, plankton study has become an important tool in assessing suitability of an aquatic environment for fish culture (Alikunhi, 1957; Mitra and Mahapatra, 1956 and Jhingran, 1991). They are of immense value as food items and play an important role in the treatment of sewage and in the natural bio-remediation of polluted waters. However, some plankton form a harmful bloom that may cause high mortality among the aquatic organisms and pose a serious threat in the water supply for domestic and industrial use (Venkateshwarlu and Hosetti, 2002).

Plankton varies qualitatively and quantitatively with depth, site, time and season. They also differ in different water bodies according to the source of water, its organic and inorganic contents and with geological, biological and climatic factors. Since very little is known about the planktonic diversity of freshwater bodies of different qualities and, moreover, information on the plankton organisms of different freshwaters, located in Northern India, is assorted and incomplete, the present work was undertaken to make qualitative and quantitative assessment of the plankton organisms in these wetlands of Aligarh. Seasonal variations in the periodicity and population dynamics of different groups of plankton in relation to various physico-chemical factors were studied in the present investigations on these wetlands.

METHODOLOGY

Water samples for plankton analysis were collected from the three wetlands (CP1, CP-2, and MP) over a period of 17 months from August, 2000 to December, 2001. For *phytoplankton* analysis, 500 ml water sample was taken and treated with 5.0 ml of Lugol's reagent (Edmondson, 1959). After 24 hours of the addition of Lugol's solutions, qualitative and quantitative analyses were made of 20 ml concentrate, which was obtained by siphoning the supernatant liquid. The genera of phytoplankton were identified and enumerated following the works of Edmondson (1959), Needham and Needham (1962), Nayar (1971) and Tonapi (1980). Phytoplankton were counted by drop count method using Whipple ocular micrometer method. The results were ultimately converted to number of organisms per ml. of water following Welch (1948). Colony counts were made for *Microcystis*, *Anabaena* and *Nostoc*.

Zooplankton samples were collected from surface waters by filtering 100 litres of water through plankton net (mesh size 30 μm) taking care not to disturb the water more. Samples were washed out into wide mouth bottles and preserved with 5 percent Formaldehyde solution. For analysis, two sub-samples of zooplankton were taken into a Sedgwick-Rafter cell and identification of zooplankton and their countings were made under an inverted microscope (*Metzer*) following the works of Edmondson (1959), Needham and Needham (1962), Nayar (1971), Pennak (1978), Tonapi (1980), Sharma (1983, 1987, 1990, 1996, 1998, 2000 and 2001). The zooplankton were identified up to species level whenever it was found possible. The results were then expressed in number per litre.

Fishes were identified following the works of Day (1958) and Talwar and Jhingran (1991). Insects were also identified following the works and guidelines of Edmondson (1959), Needham and Needham (1962) and Pennak (1978).

RESULTS AND DISCUSSION

Phytoplankton: Phytoplankton are natural inhabitants of water bodies. Investigations carried out over the past fifty years have shown that the phytoplankton communities in water are not haphazard assemblages but they are organized structures and their response to ecological factors is often definite. They are used to evaluate the water quality. The earliest attempts in this direction were made by Strom (1927 to 1928) and Pearsall (1932). Later, several workers have made important contributions. Among them are Prescott (1951), Carter (1971), Cairns *et al.* (1972), Gunale (1991), Rao *et al.* (1993), Agarwal *et al.* (1995), Raju and Durani (1996) Dayanand *et al.* (2002), Dash (2002) and Hosmani (2002).The species succession of phytoplankton is a well known phenomena. Phytoplankton ecology has been one of the most popular areas of aquatic ecology (Wetzel, 1983). A number of explanations have been advanced to account for species diversity in phytoplankton communities that is much higher than would be anticipated for theory and mathematical derivations. If environmental conditions change rapidly, the advantages gained by one species that is a better competitor may exist long enough to result in the competitive exclusion of the other species. Thus differences in the efficiencies of resource utilization among species may be too small for competitive exclusion to occur before conditions change (Wetzel, 1983).

Different groups prefer different kinds of water bodies. For instance, *Diatoms* prefer clean water bodies whereas *Chlorophyceae*, *Cyanophyceae* and *Euglenophyceae* prefer enriched waters having high load of organic pollution.

Total phytoplankton population of these three wetlands is listed in Table 12 to 14 and illustrated in Figs. 9, 10, 10a, 10b. In the present study, phytoplankton comprise five major groups, namely *Myxophyceae (Blue-green algae)*, *Chlorophyceae* (*Green algae*), *Desmidiaceae* (*Desmids*), *Bacillariophyceae* (*Diatoms*) *and Euglenophyceae* (*Euglenoids*). The order of abundance in these wetlands was found to be, *Chlorophyceae* > *Myxophyceae* > *Bacillariophyceae* > *Euglenophycea* > *Desmidiaceae.*

The phytoplankton, which could be identified, includes 27 genera in CP-1, 26 genera in CP-2 and 22 genera in MP. During the present investigations, quantitative counts of the species belonging to one genus were usually grouped together, whenever their separation was found difficult or uncertain.

In CP-1, total number of phytoplankton varied from 213/ml (September, 2000) to 133/ml (July, 2001). In CP-2, their total number ranged from 144No./ml (April, 2001) to 61No./ml (July, 2001) and, at MP, they varied from 122No./ml (April, 2001) to 51No./ml (November, 2000). The total phytoplankton in all the three wetlands showed a typical increase and decrease in abundance (Fig.9).

In CP-1, the first peak of total phytoplankton was noticed in September, 2000 it declines in the later months followed by an increase in April, 2001. Another peak of increase was shown in September, 2001. (Table 17a and Fig. 9).

Total phytoplankton in CP-2 were found to be high during January to May, 2001. The rest of the period has low density of phytoplankton (Table17a and Fig. 9). In MP, an increase in number of phytoplankton population was observed during January, 2001 to June, 2001, and low population of phytoplankton occurred during rest of study period (Table 17a). Generally, higher densities of phytoplankton were found during post-monsoon (CP-1) and winter and summer months in all the wetlands under investigations

Occurrence of seasonal qualitative and quantitative fluctuations in the phytoplankton populations in temperate as well as tropical climates is a common phenomenon. Even certain plankton populations apparently disappear at specified periods and reappear during others. Such temporary disappearances may be due to the fact that the species concerned either become too scarce or occur as spores, resting eggs etc. which could not be easily detected in the present investigations. But after the return of favourable conditions, they reappear. Similar observations have been observed during the present investigations (Table12 to14). Some species were detected low in certain months and high in other months. Talling (1957), Sreenivasan (1964) and Haque (1991) have reported peaks of phytoplankton during different seasons in different years. These variations in phytoplankton populations have been attributed to many factors (Patrick, 1969; Jana, 1973). According to Eloranta (1982), the fluctuations in phytoplankton standing crop depend mainly on the ratio between production and loss of cells. The primary factors for production are light energy, water temperature, carbon and other nutrients. Sedimentation, grazing, wash-out, and some parasites are the other factors causing loss of cells. Further it has been shown by Ganapati (1960), Zafar (1964,1967), Munawar (1972), Vasisht and Sharma (1975), Mathew (1975), Kaul (1977), Zutshi and Khan (1977), Sharma *et al.* (1978), Sharma (1980), Datta *et al.* (1984) and Singhal *et al.* (1986) that eutrophication, primary productivity, sewage disposal, increased human interference, industrial wastes and sewage result in a number of changes in the floristic composition of phytoplankton population. It may be concluded here, that no single environmental factor can govern the production of phytoplankton organisms. The coefficient of correlation between total phytoplankton density (No./ml) and some of the important physico-chemical parameters (Table 19) can pinpoint the influencing factors. Nutrients like phosphate showed direct correlation (Fig. 17) at CP-1, CP-2 and MP ($r = 0.317$, $p< 0.05$; $r = 0.351$, $p< 0.05$ and $r = 0.462$, $p< 0.05$); with Ca, it is negative at (Fig.20) CP-1 ($r = -0.136$, $p < 0.05$) and positive at CP-2 and MP ($r = 0.515$, $p< 0.05$ and $r = 0.315$, $p< 0.05$); with Cl (Fig. 21), it showed negative at CP-1 and CP-2 ($r = -0.711$, $p< 0.05$, at CP-2, $r = -0.283$, $p < 0.05$) and positive at MP ($r = 0.185$, $p < 0.05$); with Si, it is negative at CP-1 ($r = -0.051$, $p < 0.05$) and CP-2 ($r = -0.516$, $p < 0.05$) and positive at

MP ($r = 0.278, p < 0.05$); with NH_3-N (Fig.22), it is negative at CP-1 ($r = -0.317, p < 0.05$) and CP-2 ($r = -0.439, p < 0.05$) and positive at MP ($r = 0.687, p < 0.05$). Eloranta (1982) and many others have also stated that increase or decrease in phytoplankton is affected with levels of above mentioned nutrients.

MAJOR GROUPS

Myxophyceae (Blue-green algae): The micro-organisms, known as *blue-green algae* or sometime *Cyanobacteria,* form an unusually well defined group. Blue-green algae are not always blue-green in colour but after a little experience one can recognize them instantly under the microscope because of the characteristically homogeneous appearance, which the absence of membrane-bound organelles, such as nuclei and chloroplasts, gives to their protoplasm. However in distinguishing the smaller species from bacteria, which also lack such organelles, there may be some difficulty (Fogg *et al.*, 1973).

The blue-green algae or cyanobacteria have been among the most studied of all algal groups. It is a primitive group which is prokaryotic in cell structure like the bacteria (Wetzel, 1983). This group receives much attention and forms an important group of phytoplankton. The blue-green algae, which were predominant among the aboriginal organisms on the earth, are still quantitatively and qualitatively important in the biosphere. Study of these remarkable organisms is not only of particular intrinsic interest for biology but also of economic importance (Fogg *et al.*, 1973). The blooms of blue-green algae promote great social, economic environmental problems in fresh water ecosystems. Not only do they contribute to the formation scum and unpleasant odour, but they also affect the taste and quality of drinking water (Carmichael, 1996). In relation to animal and human health, the production of toxins by certain blue-green algae is another aspect that must be considered. In fresh waters, these blue-green algae are the major phytoplanktonic organisms able to produce biotoxins, neurotoxins (*alkaloids*) and hepatoxins (*peptides*) (Sant'Anna and Azevedo, 1995, 2000).

They are unicellular, filamentous and colonial forms, and most are enclosed in mucilaginous sheaths either individually or in colonies (Wetzel, 1983). They have been given much attention because of their relative scarcity and lack of other groups of algae. Its presence and abundance indicate the eutrophic nature of the water body (Seenayya and Zafar, 1981 and Gaur, 1994). World wide consequences of man-made eutrophication are a growing problem, especially in shallow lakes and reservoirs. This is often related to the appearance of bloom-forming cyanobacteria, many of which are able to produce toxic substances (Watanabe *et al.*, 1996), or otherwise restrict utilization of these waters (Paerl and Ustach, 1982). Consequences and problems caused by cyanobacterial blooms and toxins have been described by Falconer (1989), Vasconelos (1994), Carmichael (1996) and Falconer and Humpage (1996). In 1996, there was a dramatic case in Caruaru, North-eastern Brazil, when more than 40 people died because of cyanobacteria toxins in the water used by a hemodialysis center (Carmichael, 1998; Jochimson *et al.*, 1998 and Pouria *et al.*, 1998). It was also postulated that a rise in epilimnetic CO_2 concentration should have an impact on phytoplankton dominance patterns by favouring competitors of *Microcystis*.

The cyanobacteria are known to form nuisance blooms almost every summer (Deppe *et al.*, 1999). It has been characterized by its growth kinetics as a representative of eutrophic waters (Nicklisch and Kohl, 1983). It is able to build up structural dominance by a set of characteristics out-competing other phytoplankton organisms (Köhler, 1992) and offering protection against grazing (Lampert, 1982). Field observations (Talling, 1976) and enclosure experiments (Shapiro, 1984) suggested the main factor determining the outcome of competition between cyanobacteria and other phytoplankton groups is carbon dioxide.

In the present investigation of CP-1, CP-2 and MP wetlands, this group was found to be less abundant than that of *Chlorophyceae* (Table 12 to 14) and wide variations were observed in the species composition of this group. This group is mainly represented by species of *Microcystis*, *Spirulina*, *Oscillatoria*, *Anabaena* and *Nostoc*. Monthly average occurrence of these genera for all the three wetlands is given in Tables 12 to 14.

At CP-1, minimum number of *Myxophyceae* (20/ml) was found in December, 2001 and maximum (79No./ml) in May, 2001 (Table 12), whereas, at CP-2, the minimum number was found to be 9No./ml in December, 2000 and maximum

(49No./ml) in April, 2001 (Table 13). In case of MP, it was found in minimum occurrence (14No./ml) during December, 2000 and maximum (33/ml) in June, 2001 (Table 14). The data reveal, that blue-green algae were abundant during summer in all the three wetlands and low in winter months.

These wetlands were never found to be depleted completely in any season in the content of dissolved nutrients that indicates higher population of *Myxophyceae* in all the wetlands under investigation. Gerloff *et al.* (1952) and Seenayya (1971) have reported high nitrate concentration with the dense population of *Myxophyceae*.

Microcystis was found to be the most dominant species among the Myx*ophyceae*. It occurred throughout the period of investigation in all the three wetlands. The maximum number of this species was found in CP-1, CP-2 and MP, during September, 2000; May, 2001 and June, 2001 respectively (Table 12 to 14).

The increase in summer months and decrease in winter months in all the three wetlands were observed (Table 12 to 14). George (1962) also reported the same seasonal trend in his studies. Next to *Microcytis, Anabaena* dominated the *Myxophyceae*. It occurred throughout the present investigations in all the samples of CP-1 and MP but showed absence in few months at CP-2 (Table 12 to 14), wherein it occurred from August, 2000 to April, 2001 disappeared during May to October, 2001 and then reappeared in November and December, 2001. Such fluctuations may be due to disappearance and reappearance of favourable conditions required for their growth and production.

Oscillatoria was also recorded throughout the period of study at CP-1. In the case of CP-2, it occurred from August, 2000 to February, 2001, April, 2001 and September, 2001 to December, 2001 only. Whereas in the case of MP wetland, it showed irregular presence and in the population (Table 12 to 14).

Spirulina showed scarce and irregular presence in CP-1 and CP-2, whereas in the case of MP, it showed regular pattern and was present in good numbers in all the samples collected during the present investigations (Table 12 to 14). *Spirulina,* now has big name in the world of medicine.

Nostoc is only found in MP. It occurs in all the samples of MP in appreciable quantities than that of *Oscillatoria* (Table 14). The Chinese consider it as a delicacy and has been used as side dishes from ancient times in Japan (Watanabe, 1970). However, in certain part of the world, blue-green algae has been or is a staple article of diet (Fogg *et al.*, 1973). *Nostoc* occurs best in neutral or more usually in alkaline media. It showed slightly wide tolerance of alkaline pH.

Usually, blue-green algae have been reported to be present in high quantities in small water bodies than large ones (Hosmani, 2002). In the present investigation too, they always found in appreciable amounts. According to Palmer (1969), the occurrence of *Anabaena, Nostoc* and *Microcytis* is the indication of organic pollution and eutrophication.

The occurrence of these organisms in abundance in these wetlands, under study, shows that these water bodies are organically polluted and are at the verge of eutrophication.

Chlorophyceae (Green-Algae): *Chlorophyceae* is an extremely large and morphologically diverse group of algae, and is almost fresh water in distribution (Wetzel, 1983). In fresh waters, the *Chlorophyceae* constitutes the major group of phytoplankton. In the present investigation too, this group forms the dominating group of phytoplankton. Their existence is well represented by majority of *volvocales* and *chlorococcales* species. Important genera encountered in the wetlands under investigations are *Pediastrum*, *Crucigenia*, *Ankistrodesmus*, *Scenedesmus*, *Protococcus*, *Coelastrum*, *Chlorella*, *Tetraspora*, *Spirogyra*, *Ulothrix*, *Zygnena*, *Microspora* and *Selenastrum*. The periodicity of these genera have been shown in the Table 12 to 14. In temperate regions, high temperature and bright sunshine have been reported as favourable factors for the growth and development of green algae (McCombie, 1953; Davis, 1954). In the preset investigations, members of *Chlorophyceae* were found to vary from 39 No./ml in August, 2001 to 76 No./ml in April, 2001 at CP-1; 16 No./ml in July, 2001 to 59 No./ml in January, 2001 at CP-2. In the case of MP, it varied from 10 No./ml in September, 2000 to 38 No./ml in May, 2001. Relatively higher population density of *Chlorophyceae* was due to the richness of certain nutrients released during the decomposition of dead aquatic organisms. It is mainly due to phosphate and nitrate utilization by *Chlorophyceae* for their growth and development, as also reported by Singh (1960), Zafar (1964), Munawar (1974) and

Haque (1991). Calcium, found in the higher concentrations (Table 4), also seems to be one of the limiting factors responsible for development of *Chlorophyceae*. Mohan (1987) has reported that calcium play an important role in the distribution of green algae. All the three wetlands favour a luxuriant growth of *Chlorophycea* (Table 12 to 14) and always have enough quantities of phosphate, nitrates and calcium (Table 9 to11).

Crucigena, *Ankistrodesmus*, *Scenedesmus* and *Protococus* were the most abundant genera found in the CP-1 and CP-2 wetlands. *Spirogyra*, *Chlorella*, *Ulothrix*, *Zygnema* and *Microspora* occurred during certain months and showed their absence in some months of the present investigations (Table 12 to 14). Though they were never found to form blooms but they are equally important and contribute appreciably in the total phytoplankton biomass. Singh (1960) indicated a heterotrophic nature of *Chlorophyceae*. Lin (1972) and Bais *et al*. (1993) have reported that, besides physico-chemical parameters, the presence of *Myxophyceae* control the fluctuations in green-algae population.

Desmidiaceae (Desmids): The term desmid is used in limnology to designate those members of the conjugales that are either strictly unicellular or in which, if filamentous, the cells of the filaments are loosely connected (Hutchinson, 1967).

The waters, possessing desmids dominant phytoplankton, are chemically distinct from those which are rich in diatoms and blue-green algae (Welch, 1952; Hutchinson, 1975 and Goldman and Horne, 1983). Lefevere *et al*. (1952) made significant observations and found that the presence of blue-green algae has an antagonistic effect on the distribution of desmids.

All the three wetlands in the present investigations are eutrophic in terms of organic composition and possessed only few species of desmids (Table 12 to 14) as compared to *Myxophyceae*, *Chlorophyceae* and *Bacillariophyceae*. This group is mainly represented by the genera *Closterium*, *Cosmarium*, *Genicularia* and *Desmidium* at CP-1, CP-2 and MP (Table 12 to 14). Regarding seasonal variations in the distribution and abundance of desmid population, their numerical strength varied from 6/ml in April and December, 2001 to 12/ml in August, 2000 and May, 2001 at CP-1. In case of CP-2, it varied in the numerical strength from 5/ml in July, September and November, 2001 to 13/ml in February, 2001. It showed irregular pattern in most of the months (Table 13). MP showed the least abundance of desmid species during different months, which varied from 2No./ml in July, October and November, 2001 to 8No./ml in January and February, 2001 (Table 14). Rest of the months showed an irregular trend in its abundance during the present investigations. The abundance of the species followed the trend, *Closterium* > *Cosmarium* > *Genicularia* > *Desmidium* in these three wetlands (Table 12 to 14). *Closterium* and *Cosmarium* occurred in most water bodies suggesting that it has a tolerance capacity to varied physico-chemical conditions (Hosmani, 2002). In the present study, they were always found in all the samples collected from the three wetlands. Small water bodies have more *Myxophyceae* and less desmids while large waters have less *Myxophyceae* and more desmids (Hosmani, 2002).

Bacillariophyceae (Diatoms): The important group of the phytoplankton is the *Bacillariophyceae*. Most species are sessile and associated with littoral substrata. They are either unicellular or colonial forms (Wetzel, 1983). They, being important members of fresh-water phytoplankton, are nearly always present in significant numbers. They have been divided into *centric* and *pennate* diatoms on their symmetry and structures (Hutchinson, 1967). According to Werner (1977), diatoms contribute about 20-25% of the net primary productivity on the earth which is 1.4×10^{14} kg dry weight/year.

Diatoms are sensitive to various physico-chemical conditions, and there exists a considerable amount of literature describing the types of environment they inhabit. The important contributions in the past are from Round (1966), Zafar (1967), Palmer (1969), Patrick (1977), Kamat (1981), Nautiyal (1984), Haque (1991), Gaur (1999), Hosmani (2002) and many others.

In the present investigations, the diatoms also contributed an important group in the phytoplankton. The representing members of this group are, *Navicula*, *Nitszchia*, *Synedra*, *Cyclotella*, *Amphora* and *Diatoma*. Among them, *Navicula* and *Synedra* showed regular appearance in all the samples of the wetlands. Many of the other genera from this group showed temporary disappearance and reappeared again on return of favourable conditions (Table 12 to 14). They contribute significantly in total phytoplankton biomass (Table 12 to 14). They showed variations ranging from 18 No./ml to 54 No./ml at CP-1, 12 No./ml to 23 No./ml at CP-2 and from 10 No./ml to 37 No./ml at MP. Seasonally, *diatoms* showed their high numerical strength in the CP-1 during the months of monsoon, winter and summer (Table 12). In the case of CP-2, it was found to be high during summer and winter months. However, in case of MP, diatoms were rich in number during winter, summer and few months of post-monsoon (Table 14).

Eloranta (1982) and Mohan (1987) have estimated the importance of silica as a factor controlling the spatial and temporal distribution of the diatoms. In the present investigation, also, silica was found to be substance influencing distribution and abundance of diatoms ($r = -0.275$; $r = -0.364$ and $r = 0.170$ at $p < 0.05$, at CP-1, CP-2 and MP respectively (Table 19 and Fig. 23).

Navicula, Nitzschia and *Synedra* were most important species of diatoms and showed their regular occurrence in all the samples of CP-1, CP-2 and MP. *Cyclotella, Amphora* and *Diatoma* mostly occur in CP-1 (Table 12) and showed their irregular presence and absence at CP-2 and MP. They showed their abundance in certain months and absence in rest of the months (Table 13 and 14).

In CP-1, diatoms were present in all the sample (Table 12) showing their maximum number in May, 2001 and minimum in the months of August and November, 2001. Diatoma spp. showed very interesting distribution in CP-2, where they were recorded regularly from October, 2000 to May, 2001, disappeared from June, 2001 to August, 2001 and again reappeared during September, 2001 to December, 2001 (Table 13). This may be due to the return of favourable conditions for their growth and development. In the case of MP, diatoms showed its presence from August to September, 2000, disappeared in October and November, 2000 and then reappeared again from December, 2000 to October, 2002. It again disappeared in the month of November and December, 2000 (Table 14) showing very irregular pattern.

Euglenophyceae (Euglenoids): This group of phytoplankton consists of more than 600 species of photosynthetic form, as well as many are *apochlorotic* and few are of any importance as members of the lake plankton (Hutchinson, 1967). Although the *Euglenophyceae* is a relatively large and diverse group, few species are truly planktonic (Wetzel, 1983). Nonetheless, when conditions are favourable, the euglenoids can develop in great profusion. Almost all euglenoids are unicellular, lack a distinct cell wall and possess one, two or even three flagella that arise from an invagination in the cell membrane. They are rich in shallow water bodies, which are having rich organic matter (Wetzel, 1983).

Very little information is available regarding the ecology of *Euglenophyceae* in Indian fresh waters. Important studies conducted on *Euglenophyceae* are those of Zafar (1959), Philipose (1960), Singh (1960), Saxena (1981), Haque (1991) and Hosmani (2002). In the present study, *Euglenophyceae* group was found to be represented by only two genera, namely *Euglena* sp. and *Phacus* sp. Their seasonal distribution and variations have been given in Table 12 to 14. The highest population of this group was found in CP-1 followed by CP-2 and MP (Table 12 to 14). The densities of *euglenoids* were noted to vary between 8 No./ml to 34 No./ml at CP-1, 11 No./ml to 24 No./ml at CP-2 and 3 No./ml to 15 No./ml at MP. The higher population was found to be in the post-monsoon and winter months and the lower in the monsoon months at CP-1 (Table 12). The CP-2 showed wide variations in its abundance. It was found to be maximum in the winter and summer months and minimum in monsoon months (Table 13). But in the case of MP wetland, the higher population of *Euglenophyceae* was recorded in monsoon and winter months and lower on the onset of monsoon (Table 14). Their development in the phytoplankton occurs most often in monsoon season, strata or lake systems in which concentration of ammonia and especially dissolved organic matter is high (Wetzel, 1964). However, euglenoids are found most often in shallow waters rich in organic matter. In the present investigations of these wetlands, euglenoids are found in quite good numbers, reflecting the idea that they may be highly resistant to the changing environmental conditions and moderate supply of nutrients for their growth and development.

It has been reported that blooms of *Euglena* sp. limit the growth of their own populations resulting in abrupt disappearance (Hosmani, 2002). Most bloom-forming euglenoids are represented in smaller water bodies, while larger water bodies, like large lake, showed a poor representation (Hosmani, 2002). The majority of the species of *Euglena* and *Phacus* sometimes are also found in very small water bodies, like ditches which often have a high organic content (Hutchinson, 1967). Thus, it can be concluded that the invariable populations of *Phacus* sp. and *Euglena* sp. in all these wetlands indicates their eutrophic nature.

***Zooplankton*:** Biological organisms are diagnostic in determining the health of aquatic ecosystem (Loeb, 1994) because they are the fundamental sensors responding to stress affecting these biotopes. Any stress imposed in these environs manifests its impact on inhabitant communities and results in restructuring of originally present biotic components.

Studies on freshwater bodies, natural or man-made, have gained much importance in recent years mainly because of their multiple uses. Several workers have attempted to study the hydrobiological profile of varied water bodies with intent of assessing the quality of water (Bhatt and Pathak, 1992) and diversity of the organisms (Mammaril and Fernando, 1978; Fernando, 1980; Swar and Fernando, 1980; Lim and Fernando, 1985; Jeye and Fernando, 1986; Reddy, 2001 and Sharma, 2001). The diversity of zooplankton of Indian waters has been reported by Rajendran (1973), Victor and Fernando (1979), Patil and Gouder (1985), Hazarika and Dutta (1988), Sharma (1995, 1996, 1998, 2001), Sharma and Sharma (1999, 2001), Singh (2000) and Reddy (2001). These studies indicate that physico-chemical qualities of water are the major influencing factors for the variations in the diversity of zooplankton (Swar and Fernando, 1980).

Zooplankton forming the most important animal group of aquatic environment, constituting a major portion of the diet of fish and other aquatic organisms. The majority of economically important freshwater teleosts are known to pass through stages in their life history when they subsist on zooplankton for food. Besides, many adult major carps of commercial importance are reported to feed selectively on these organisms.

Zooplankton are small organisms that float freely in the water column of lakes, ponds, wetlands, rivers and oceans. Their distribution is primarily determined by water movements and mixing. They vary in size from ultra-to macro-zooplankton.

Zooplankton represents an important link in the trophic structure of these aquatic environments, by rendering a part of the primary production available to higher trophic levels. As a result of grazing, zooplankton may be able to control phytoplankton at low level under certain conditions (Verity and Smetacek, 1996). Although many differences exist between the structure of freshwater and marine zooplankton communities (Lehman, 1988), the main herbivore component in biotic environments is formed by crustaceans (Jak, 1997). By virtue of their role in converting phytoplankton into food (second link in the aquatic food chain), suitable for fish and aquatic mammals of economic value to man, they are of great importance in fisheries research.

As per Gannon and Stemberger (1978), the role of zooplankton as indicators of trophic conditions has been acquired mostly on investigations on lakes in cold temperate region. The warm tropical water bodies were paid a little attention and, therefore, zooplankton has been a subject of study by many workers within and outside country. Notable contributions are those of Edmondson (1959), Arora (1961, 1966), Hazelwood and Parker (1961), Nayar (1965), George (1966), Khan (1969), Mahajan and Singh (1973), Ruttner-Kolisko (1974), Vashist and Sharma (1976), Rao and Mohan (1977), Mammaril and Fernando (1978), Gulati (1978), Pennak (1978), Pontin (1978), Verma *et al.* (1978), Victor and Fernando (1979), Fernando (1980, 1986, 1994), Swar and Fernando (1980), Mahajan (1981), Battish (1992), Dumont and Pensaert (1983), Pejler (1983), Ricci (1983), Sharma (1983, 1987, 1991, 1992, 1995, 1996, 2001, 2002), Sladecek (1983), Dussart and Defaye (1985), Dussarat and Fernando (1985), Lim and Fernando (1985), Jeye and Fernando (1986), Berzins and Pejler (1987), Deb *et al.* (1987), Sharma and Michael (1987), Michael and Sharma (1988), Sharma and Sharma (1990, 1997, 1999), Wallace and Snell (1991), Reddy (1994, 2001), De Smet (1995, 1996) and Segers (1995, 2001).Specifically, Green (1976), Zutshi and Vaas (1982), Yousuf *et al.* (1983), Fernando and Kanduru (1984), Dumont (1994), Sharma (1998), Khan and Sinha (1999) etc. have studied responses of zooplankton to various physico-chemical parameters, including nutrient loading (Mc Cauley and Kaff 1981; Dodson, 1992), on acidification (Brett, 1989; Keller and Yan, 1991; Marmorek and Korman, 1993), contaminants (Yan *et al.*, 1996), fish density (Carpenter and Kitchell, 1993), sediment inputs (Cucker, 1997), cyclomorphic changes (Khan and Alam, 1999; Alam *et al.*, 2002 a, b) .

In the zooplankton community of an ecosystem, the main role is played by only few commonly occurring species (Anderson, 1971; Patalas, 1972). Anderson (1974) found that only a few numerically abundant species contributed 27% of the total communities of 340 lakes and ponds of Canada. Yousuf *et al.* (1983) found that 35.5% of total community were contributed by only four species in some fresh-water lakes and ponds of Kashmir. Generally, temperature and food supply have been found to govern the population dynamics of zooplankton species, particularly in temperate region (Elgmork, 1959, Hazelwood and Parker, 1961, Elbourn, 1966, Vijveberge and Richter, 1982). Possibility of other factors controlling the plankton distribution was realized only in the present century. Planktonic organisms vary quantitatively and qualitatively with the depth, site, time and the season of collection (Chourasia and Adoni, 1985).

During present investigations, all the three wetlands (CP-1, CP-2 and MP) were characterized by a number of species, which control the bulk of zooplankton density (Table 15-17). Very little is known about the plaktonic diversity of wetlands of different qualities. Some important contributions are those of Gopal (1982), Sharma (1983, 1987, 1996, 1998, 2001a, 2001b), Sharma and Michael (1987), Chaudhury (1998), Sharma and Sharma (1990, 1999) etc. Since information on the zooplankton fauna of different wetlands is assorted and incomplete, the present investigation was made on some wetlands of Aligarh region to understand the seasonal variations in periodicity and abundance of different zooplankton groups. In the present investigations, zooplankton comprise four major groups, namely *Rotifera*, *Cladocera*, *Copepoda* and *Ostracoda* alongwith *Eggs* and *Nauplii*. The zooplankton, encountered and which could be identified, include 22 genera at CP-1, 17 genera at CP-2 and 14 genera at MP (Table 15 - 17). Qualitative counts of the species belonging to one genus were usually grouped together, wherever their separation was found difficult or uncertain.

Zooplankton showed wide variations in different seasons both in quality and quantity (Table 15 to 17). The higher magnitude of zooplankton population was recorded in some months of monsoon and post-monsoon, 2000, while lower magnitude was recorded in the end of 2001 at CP-1 (Table 15). At CP-2, higher numerical strength occurred in the end of post-monsoon and winter months of 2000 and 2001 and lower in the summer of 2001 (Table 16). In the case of MP, the higher numbers were found in the samples of monsoon and at the onset of post-monsoon, 2001 and lower in the winter of 2001 (Table 17).

Seasonal changes in the zooplankton population in these wetlands nearly followed the same trend as that of phytoplankton (Table 17a and Fig. 9 and 24).

MAJOR GROUPS

The group *Cladocera* showed dominance and *Ostracoda* was found least abundant both qualitatively and quantitatively (Fig. 11-11a) in the present investigations.

The ***Rotifera*** (*Rotatoria*) is a group of the pseudocoelomate animals and a minor phylum of invertebrates, commonly termed as '*wheel-animalcules*' because of their characteristic '*Wheel organ*' or *corona*. The term *Rotifera* or *Rotatoria* had long been invariably used for this primitive group. Their nomenclature status was first questioned and reviewed at international symposium held at Uppsala, Sweden in 1982 (Ricci, 1983), wherein the former term was accepted to be valid by the rotiferologists for all future applications. They are totally freshwater except only two genera and their few species, which are marine (Wetzel, 1983). *Rotifers* are the most important soft-bodied invertebrates in the fresh-water plankton and characteristically inhabitants of inland waters (Hutchinson, 1967). These organisms were presumed to be a product of the aerobic phase in the development of our planet (Sladecek, 1983). About three-quarters of the rotifers are sessile and associated with littoral substrates. Approximately, 100 species are completely planktonic and form a significant component of zooplankton. These fascinating creatures, in some species, have disc like ciliated corona, which resemble to a pair of revolving wheels owing to the synchronized beating of coronal cilia. The rotifers occur in an endless variety of aquatic and semi-aquatic habitats, including the limnetic and deepest regions of the largest lakes and smallest puddles. They are found in damp soil and vegetable debris, in mosses that may be wetted or dampened only occasionally (Pennak, 1978). In terms of biomass, rotifers certainly cannot compete with the larger crustaceans, but their rapid reproduction and fast development rate means that rotifers can account for between 10 to 44% of the total zooplankton (Herzig, 1987). According to Pennak (1978), if we were to designate a single major taxonomic category that is most characteristics of fresh waters, it could only be the phylum rotatoria.

Rotifers have some characters very specific in the animal kingdom, for example all rotifers possess a species-specific number of cells at birth (they are strictly entelic) and grow by increasing cell size and not cell number. The oocytes are also fixed for each rotifer species (Pagani *et al.*, 1993).

Rotifers show a remarkable diversity of morphological, morpho-functional and ecological characters, which complicates their taxonomic arrangement and their systematics (Kutikova, 1983). Referring to the status of the Indian rotifers, only 330 species spread over 63 genera and 25 families have so far been documented (Sharma, 1998). The credibility of ecological, genetic, biochemical and other studies on rotifers relies heavily on the correct identification of the organisms involved, but at the same time the existence of parthenogenetic reproduction, either facultative or obligatory, high mutation rates and polymorphism, make the delimitation of rotifer species extremely uncertain, which is still based on morphology (Ruttner-Kolisko, 1989).

They have ability to colonize, diversified biotopes, depict interesting reproductive and population strategies, and certain taxa show unique *ecotypic* and *cyclomorphic* variations. They also act as valuable indicators of trophic conditions of water (Sladecek, 1983) and appear to be more sensitive indices of changes in water quality (Allan, 1976). They also serve as essential food source for invertebrate and vertebrate predators (Herzig, 1987). Rotifers constitute an important trophic link and play a vital role in the food chain of fishes as animal food, which supplies amino-acids, fatty acids, vitamins, minerals etc. (Watanabe, 1978, Alam *et al.*, 1989), and also play an important role as grazers, suspension feeders and predators within the zooplankton community (Herzig, 1987). Consequently, they are often regarded as important competitors of the large crustaceans. Though cladocerans out compete rotifers in the present study but this is not surprising, since *daphnids* are more than

10 times larger than *rotifers* and their clearance rates is also higher than *rotifers* (Burns and Rigler, 1967; Jones *et al.*, 1979; Bogdon and Gilbert, 1982).

Several important monographs which collated formal records from various zoogeographical regions were published by Beauchamp (1965), Donner (1965), Kutikova (1970) and Koste (1978). In addition, classical general publications relating to rotifers are those of Donner (1965) and Nogrady *et al.* (1993), while some other noteworthy diagnostic works are those of Edmondson, (1959), Ruttner-Kolisko (1974), Pontin (1978), Hofmann (1980, 1983, 1987), Wallace and Snell (1991), Shiel (1995), De Smet (1995, 1996), De Smet and Purriot (1996), Sharma (1991, 1995, 1996, 1998, 2000, 2001), Melone *et al.* (1998) and Sharma (1999, 2001).

In the present studies, this group is represented by species *Brachionus* sp., *Keratella* sp., *Notholca* sp., *Filinia* sp., *Testudinella* sp. and *Asplanchna* sp. Many of the species recorded in the present study showed seasonal variations (Table 15, 16 and 17). This may be due to the fact that some forms vary in their mode of nutrition and some occupy different waterbodies having changed physico-chemical characteristics.

In the present study, maximum numbers of rotifers were recorded in CP-1 during monsoon and post-monsoon months of 2000 and 2001 and minimum during winter and early summer of 2001 (Table 15). At CP-2, the rotifers were found to be maximum in some post-monsoon months and winter of 2000 and 2001, while minimum numbers were found in the months of summer and monsoon, 2001 (Table 16). Whereas in the MP, it showed an interesting pattern in the occurrence of rotifera. The maximum numbers were recorded during monsoon and post-monsoon and minimum in summer (Table 17). Among rotifers, the genus *Brachionus* was represented by two species in CP-1 and CP-2 and single species in MP. *Brachionus calyciflorus* was one of the most important species that occurred throughout the investigations in all the three wetlands. It occurred in quite good numbers except in few months at CP-2 (Table 15, 16 and 17).

Brachionus angularis was recorded in appreciable quantities only in CP-1 and CP-2, and found absent in MP (Table 15). Among the common and widely distributed species of *Brachionus*, *B. calyciflorus* and *B. angularis* are common species in Indian waters. They depict cyclomorphosis and exhibit different eco-types (Khan and Alam, 1999).

Brachionus sp. has also been designated as indicator of organic pollution in eutrophic water bodies (Pejler, 1957, Rao and Mohan, 1977 and Sharma, 2001). In the present study, their presence indicates that the wetlands are approaching towards eutrophication. They were found to dominate the rest of the rotifer species (Table 15 to 17).

Keratella sp. is regarded as the most important indicator species of mesotrophic and eutrophic water bodies (Maemets, 1983). It is represented by only one species, *Keratella tropica* (Table 15 to 17). *Keratella tropica* is cosmopolitan in distribution and common in inland water bodies. The genus *Keratella* contains a large number of species, some of which exhibit or appear to exhibit striking seasonal morphological changes (Hutchinson, 1967).

Filinia sp. have also been reported as a representative of eutrophic waters (Pejler, 1957 and Sharma, 2001). In all the three wetlands, they showed their good presence and were always found in appreciable quantities throughout the investigation period. They attain a definite pattern of distribution. Because of their smaller size, they have threshold food levels for attaining positive population growth rather than larger species as also reported by Stemberger and Gilbert (1985). *Filinia* sp. being an important species, was found in almost all the samples collected from the wetlands under study. Their maximum number was recorded (28No./L) in MP in the month of August, 2001. The CP-1 showed its maximum (6No./L) in the month of June, 2001, and CP-2 (8No./L) in the month of December, 2000. The present findings indicate that proliferation of the *Filinia* sp. at MP may be due to high nutrient status and rich organic matter (Table 17). In the present study, some more species of rotifers were encountered in the samples of CP-1, like *Testudinella* sp., *Asplanchna* sp. and *Lecane* sp. but their presence was almost negligible and showed no definite pattern. They were found to be absent in the water samples collected from CP-2 and MP.

In addition, another species, *Notholca* sp., showed very irregular abundance in these wetlands (Table 15 to 17). Like so many other plankton and littoral organisms, rotifers exhibits periodic and sometimes quite striking cycles of abundance during the year (Pennak, 1978). Various investigators have designated certain species of this group as *monocyclic*, *dicyclic*, *polycyclic*, *acyclic* and *perennial*. As emphasized by Pennak (1949), the cycles of abundance for plankton species are highly variable within each species, variable from year to year within a single lake, and especially variable from one lake to another. The species encountered in the present study may be grouped in the *monocyclic*, *dicyclic* or *polycyclic* after following Pennak's (1978) classification.

Studies on the sensitivity of the rotifers to various ecological factors are useful for biomonitoring of aquatic ecosystem. In the present study, rotifers in general showed distinct peaks of abundance. Coefficient of correlation (r) of different physico-chemical parameters with rotifer population was computed (Table 19). The temperature tolerance range (12-37°C), as has been experimentally established by Arora (1966) for certain rotifers, was never found to be critical in the present investigations. Rotifera, as a group, appear to be temperature facultative and marked temperature changes on either side of temperature optima of different species seem to influence their population density (Table 15 to 17).

Pejler (1957) considered rotifers as pH insensitive. He concluded that pH may not have any direct bearing on rotifer population. Hofmann (1977) also indicated that some species can tolerate high pH (10.6) conditions. Nevertheless, the range of pH (5.5 to 12.6), which these organisms are reported to withstand (Arora, 1966) is too wide to suggest their pH sensitivity. In the present investigation, a negative relationship was found at CP-1 and CP-2 and positive at MP (Table 19) between these two variables.

Transparency and turbidity exhibited positive relationship with rotifers population at CP-1, CP-2 and MP (negative at MP with transparency). Datta and Bandyopadhyay (1985) have reported negative relationship with these variables.

Moreover, the predation by planktivorous fish in these wetlands also plays an important role in lowering the rotifer population density. Models of population can be used to decrease the patterns of population densities in space and time (Halbach, 1970b). The whole causal chain in rotifer population dynamics, according to Halbach

(1984) is ecological factors→ physiological characters → life table data → population parameter → population dynamics.

Cladocera, comprise a group of primitive and usually microscopic crustaceans to which the general name of '*Entomostraca*' was formerly applied. The members of this group are also commonly termed as '*Water-fleas*' because of their characteristic '*jerky*' swimming action of locomotion (Dodson and Frey, 1991). Although, the cladocerans were invariably treated as a distinct order under the *Brachiopoda* during their nearly three-century old taxonomic history, recent developments during the last couple of decades raised questions regarding their phylogenetic relationships and composition of the branchiopods (Dodson and Frey, 1991) in general and the classification of this group in particular. The status of *Cladocera* is, therefore, controversial. Based on traditional morphological analysis, *cladocera* is now regarded as an 'artificial group' representing four orders of *Branchiopoda*, namely *Ctenopoda*, *Anomopoda*, *Onychopoda* and *Haplopoda* (Korovchinsky, 2000). This group is even incorporated in different sub-classes of *Crustacea* (Starobogator, 1986, Fryer, 1987).

Inspite of this debate, the usage of the term '*Cladocera*' continues to be practically convenient (Shiel, 1995; Korovchinsky, 1996, 2000 and Ingram *et al.*, 1997). In contrast, modern cladistic analysis (Martin and Cash-Clark, 1995; Olesen, 1998 and Negrea *et al.*, 1999) and recent genetic as well as molecular evidences (Hebert and Taylor, 1997; Crease and Taylor, 1998) strongly support monophyly of the group and, hence, suggest the retention of the long-used name '*Cladocera*' for this particular order of micro-crustaceans (Sharma, 2001).

Because of their interesting habits, their availability in nearly all types of freshwater habitats and their complex but easily studied anatomy, the '*water fleas*' have been favourite objects of observation by both amateur and professional biologists ever since the invention of the microscope (Pennak, 1978). The importance of *Cladocera* in the trophic dynamics of freshwater ecosystems, being the main component of zooplankton, has long been recognised (Sinha and Khan, 1998). They are the consumers of first order, directly drawing energy from primary producers of the ecosystem viz. phytoplankton. In turn, form the food for planktivorous fishes and other invertebrates, transferring energy to higher trophic levels. Besides, they have also been reported to be reliable indicators of eutrophic nature of water bodies (Sinha and Khan, 1998; Sharma, 2001). The *cladoceran* in general and the representatives of the largest family *chydoridae* in particular are considered to be excellent '*guide forms*' in paleo-limnological endeavours and help in resurrecting the trophic history of ancient lakes and reservoirs (Sharma, 2001).

The greatest abundance of cladocerans is found near the vegetation in lakes, ponds and pools (Tonapi, 1980). These crustaceans vary from 0.2 to 3.0 mm or little more. Though it appears as a bivalve, the carapace on the body is actually a single fold of cuticle (Tonapi, 1980; Wetzel, 1983).

The *cladocera,* as a group, had attracted considerable global attention of naturalists as well as of aquatic biologists because of their global distribution and occurrence. Significant works on these organisms are those of Lillijeborg (1900), Birge (1918), Sramek-Husek *et al.* (1962), Smirnov (1976), Chiang and Du (1978), Pennak (1978), Tonapi (1980), Idris (1983), Khan (1983a, b), Goldman and Horne (1983), Wetzel (1983), Fernando and Kandura (1984), Michael and Sharma (1988), Sharma and Michael (1987), Sharma and Smita (1990), Sharma (1991, 2001), Korovchinsky (1992, 1996, 2000), Dumont (1994), (1994), Fernando (1994), Shiel (1995), Ingram *et al.* (1997), Olesen (1998), Crease and Taylor (1998), Sinha and Khan (1998), Hofmann (1998) and Negra *et al.* (1999).

Realising the importance of the group and lack of specific knowledge in the region, the present investigations are carried out in relation to the seasonal and spatial variations in the wetlands of Aligarh region. The study revealed diverse cladoceran occurrence in these wetlands. The group is represented by *Daphnia pulex*, *Daphnia parvula*, *Diaphanosoma* sp., *Moina* sp., *Ceriodaphnia* sp., *Alonella* sp., *Leptodora* sp., *Simocephalus* sp., and *Bosmina* sp. Qualitative analysis of the samples from these wetlands shows species richness. Highest number of species belonged to genus, *Daphnia* (Table 15 to 17). Highest cladocera density was recorded in CP-1 followed by MP and CP-2 (Figs.11, 11 a, b). In CP-1 the highest number (58No./L) was found in the month of November, 2000 and the lowest (20 No./L) in the month of July, 2001. In CP-2, cladocera population was found to be high (38 No./L) in December, 2000 and low (8 No./L) in May, 2001. In the case of MP, the highest number of cladocera (45 No./L) was recorded in October, 2001 and lowest (14 No./L) in January, 2001. Out of all cladoceran species recorded in the present investigations on these wetlands, few species in each wetland formed the bulk of density throughout the year.

Individual species density revealed significant differences among different wetlands. *Daphnia pulex*, *D. parvula*, *D. carinata* and *D. magna* accounted for large portion of total cladoceran density almost throughout the investigations in CP-1 (Table 15), whereas in the case of CP-2, *Daphnia magna*, *Daphnia pulex* and *Daphnia carinata* contributed significant quantities of cladocerans (Table 16). The pattern was different in MP, wherein *Daphnia* sp., and *Simocephalus* sp. dominated the cladocera group (Table 17).

It was also observed that total cladoceran densities followed almost similar seasonal patterns in all the three wetlands. They are higher in post-monsoon and winter months and low in summer and monsoon months at CP-1. In the case of CP-2 the higher counts were recorded during winter months and low in summer, whereas MP was found to be highly populated with cladocerans during monsoon and post-monsoon months (Table 15 to 17). Other individual species behaved differently in different wetlands (Table 15 to 17).

Daphnia pulex was found to be present in all the samples of CP-1, CP-2 and MP, whereas other species of *Daphnia* like *D. parvula*, *D. carinata* and *D. magna* were encountered only in CP-1 and CP-2. In the case of CP-1, *Daphnia parvula* was found to be present in all the samples except during June and July, 2001 (Table 15). *Daphnia carinata* also showed regular occurrence, except in August, 2001 at CP-1. In the case of CP-2, it has sporadical occurrence (Table 16). *Daphnia magna* was encountered in appreciable numbers in CP-1 and CP-2 during the period of investigations.

Ceriodaphnia sp. was noted in all the three wetlands. It was found to be maximum in number during monsoon and post-monsoon months at CP-1. In the case of CP-2, it showed irregular pattern, where it was found absent during August to September, 2000, March, 2001 and June to September, 2001 (Table 16). In MP, *Ceriodaphnia* sp. was encountered in the samples of August to September, 2000 followed by a sudden disappearance during post-monsoon, winter and summer, 2001. It reappeared in August and September, 2001 and then again disappeared in the following months of the study (Table 16).

Moina sp. was noted in all the three wetlands. It was encountered in all the samples of CP-1 and CP-2, while in MP it was found to be absent in January, 2001 (Table 15 to 17).

The occurrence of *Diaphanosoma* sp., *Simocephalus* sp., *Alonella* sp. and *Leptodora* sp. in these wetlands have showed wide fluctuations in their existence providing evidences of favourable and unfavourable conditions due to incoming sewage effluents and other surface run-off from the catchment areas during different periods of investigations. According to Sharma and Michael (1987), limnetic zooplankton communities in Indian waters are invariably dominated by species of *Daphnia* and *Ceriodaphnia*. *Bosmina* forms a dominant component in hilly regions of North-East India. In tropical part of this country, *Daphnia* sp. and *Ceriodaphnia* sp. dominated the limnetic cladocera and represent eutrophic and tropicopolitan forms. In the present study, the pattern of occurrence of these species of cladocera is quite similar to the above findings.

Diversity and species richness of cladocerans have been discussed by several workers both in temperate and tropical water bodies. As far as tropical wetlands are concerned, there are two divergent viewpoints. Earlier concept, advocated by a number of workers (Fernando and Kaundura, 1984; Green, 1990), asserted that the diversity of cladoceran fauna in temperate water bodies is considerably more than in tropical water bodies. The reasons cited for such improvishment of species include intense grazing pressure by planktivorous fishes throughout the year resulting elimination of large sized species (Fernando, 1994) and eutrophic nature of tropical waterbodies restricting species richness (Green, 1976 and Ravera, 1996). Refuting this viewpoint, Dumont (1994) mentioned that diversity of cladocera in tropical waters is in no way lesser than in temperate waters. To prove this he cited that out of 290 cladoceran species, known from the world, almost 150 species are exclusively confined to tropical water bodies with 40 species common to both tropical and temperate waters. During present investigations the cladoceran richness was found to be quite *moderate* where about 10 species were observed in the wetlands under study.

Dumont (1994) classified a water body as *rich* if there are 30-50 species. This range appears to be extremely high as far as Indian water bodies are concerned. A survey of literature revealed that the number of cladoceran species reported from any single water body of the country generally varied between 5-10 species (Singh and Pandey, 1991; Sinha *et al.*, 1992) excepting few cases (Ganapati, 1943; Kumar and Dutta, 1994). Since most of the studies including the present one were undertaken from general limnological view points, where proper taxonomic attention was not given to cladocera as well as other planktonic species, there is always a possibility of many species being over looked. This can also be judged from the detail taxonomic works of Sharma and Michael (1987), Michael and Sharma (1988), Sharma and Sharma (1990), Sharma (1991, 2001) and Venkataraman and Das (1993).

However, the diversity of cladoceran like any other faunal group is affected considerably by various local factors operating in the particular water body. Increased eutrophication due to extensive use by surrounding floating human population have resulted in the improvement of many susceptible species from these wetlands during the present investigations. Further, the increased grazing by planktivorous fishes in these wetlands has limited the cladoceran species and population richness.

Copepods are very ancient arthropods and the diminutive relatives of crabs and shrimps. In terms of their size, diversity and abundance, they are also often called as *'water fleas'* in common with many other small *crustacea* (Reddy, 2001). Till now, over 10,000 copepod species are known including thousands of free-living species with highly varying body shapes and a great number of parasitic and semi-parasitic forms with extremely reduced morphology (Reddy, 1994, 2001). A plankton sample from the open waters of any pond or lake will always include copepods (Cole, 1983).

Like the cladocerans, the copepods are universally distributed in the limnetic, benthic and littoral regions of freshwaters. They are either absent or present in small numbers in rapid headwater brooks and streams (Pennak, 1978). A vast majority of copepods are confined to marine and brackish waters, only a small fraction, about

2000 species inhabit freshwaters (Reddy, 2001). They inhabit many of the habitats such as lakes, reservoirs, wetlands, tanks, ponds and pools (Tonapi, 1980).

The free-living copepods are separable into three distinct groups, the suborder *Calanoida*, *Cyclopoida* and *Harpacticoida* (Hutchinson, 1967; Wetzel, 1983). Although accurate identification is based largely on morphological details of appendages, several general characteristics delineate the major groups (Wetzel, 1983).

Members of the families, *Cyclopidae* in the *Cyclopoida* and *Diaptomidae* in the *Calanoida*, are highly successful in the freshwaters and mostly represent the Indian planktonic copepoda (Reddy, 2001). The body size of the copepods ranges between 0.3 to 3.5mm (Tonapi, 1980), whereas American species vary from 0.3 to 3.2mm in size and greatest majority are less than 2.0mm long (Pennak, 1978). The first segment of thorax is fused with head to form a compound cephalic somite. The body seems to be divided into two parts (i) *Metasoma*, which is immovable portion and consists of head and most of the thorax segments which are six in number, (ii) *Urosome*, which is movable and articulate with the *metasome*. It consists of last one or two thorax and all abdominal segments. The articulation is in between the thoracic segments, six and seven, in case of *Harpacticoida* and *Cyclopoida*. The *Calanoides* have five urosomal segments in male and two to three segments in female.

The diversity and distribution of copepods have been reported by Rajendran (1973), Mamaril and Fernando (1978), Swar and Fernando (1980), Fernando (1980), Dussart and Fernando (1985), Dussart and Defaye (1985), Jeye and Fernando (1986), Hazarika and Dutta (1988) and Reddy (1994, 2001).

As to their importance, copepods are significantly primary and secondary consumers in aquatic food chain. Their grazing contributes to the transfer of algal primary production to higher trophic levels. In other words, copepods can make organic material available to higher trophic levels in a larger pellet form, thus saving the foraging energy of their predators (Reddy, 2001).

Among the major groups of zooplankton in the present study, *copepods* were rather comparatively less abundant than that of *cladocerans* and *rotifers*, but higher than *ostracoda*. The representative members of the *copepods* family belong to

Cyclops sp., *Canthocamptus* sp., *Diaptomus* sp. and *Limnocalanus* sp. (Table 15 to 17).

The copepod species richness revealed diverse occurrence in these wetlands. The higher copepod population densities in CP-1 were recorded during monsoon, post-monsoon and summer months. The wetland showed highest number of copepod (29No./L) during February, 2001 and lowest (9No./L) in June, 2001. In CP-2, the pattern of the seasonal density of total copepods showed wide fluctuations. They were found to be high during monsoon, post-monsoon and winter months with highest number (39No./L) in December, 2000. Low population densities (10No./L) were recorded in the summer months, May and June, 2001 (Table 16).

However, in the case of MP, the highest peak of occurrence was observed during the onset of monsoon, having maximum population density (55No./L) during July, 2001 and minimum population (13No./L) was found in January, 2001. The pattern of fluctuation was almost similar in all the wetlands (Table 17). Seasonal variations of this group have also been reported by other workers (Patil and Gondar, 1985; Kaushik and Sharma, 1994). It has been reported that temperature appears to be the major factor in the seasonal fluctuations of copepods (Chen, 1965). The peak population may occur in different months of the year indicating the influence of other factors (Mathew, 1975). Among the representative species of copepods, *Cyclops* sp. dominated the group in these wetlands, followed by *Diaptomus* sp. and other representatives of the group (Table 15 to 17). The *Limnocalans* sp. was only recorded from the samples of MP wetland (Table 17). *Canthocamptus* sp., showed its irregular pattern in its presence and absence during different months at CP-1 and MP (Tables 15 to 17).

In the present study, copepods showed wide fluctuations in different seasons. Some of the species showed the pattern of disappearance under unfavourable conditions and reappearance when the conditions become favourable. Many organisms have seasonal cycles that cannot be explained by abiotic factors alone. Diapausing copepods can be viewed as general models for such varieties. For example, the production of diapausing resting eggs in *Diaptomus* has been shown to be related to fish predation (Hairston and Dillon, 1990). Various copepods perform a diapause in summer months and reproduce in spring months. Their nauplii develop until they reach the fourth copepodite stage, then they burry themselves in the sediments and stay there throughout the summers. The copepodites leave the sediment in fall and complete their life cycle. As cyclopoids can be very abundant in eutrophic waterbodies, their life cycle can determine the seasonal pattern of the zooplankton (Lampert, 1993, 1997).

Spindler (1971) has suggested that day length is the proximate factor for entering diapause behaviour, but the ultimate factor is not evident. Further, factors like salinity, temperature, predation and food etc. affect differently to the invertebrate and vertebrate predators (Hall *et al.*, 1976; Gliwicz *et al.*, 1981). Unlike vertebrates, invertebrate predation affects the planktonic composition by removing small sized and sometimes middle-sized individuals (Dodson, 1974; Gliwicz *et al.*, 1981; Kerfoot, 1987; Hanazato and Yasuno, 1989 and Lunte and Luecke, 1990). Swar and Fernando (1980) suggested that physico-chemical qualities of water are the major influencing factors for the variation in the diversity of zooplankton organisms.

Copepods have been reported to be good indicators of water quality (Patalas, 1972; Cairns, 1974; Gannon and Stenberger, 1978; Khan and Rao, 1981 and Mahajan, 1981). Although copepods exist under a wide range of environmental conditions yet many species are limited by temperature, dissolved oxygen and other physico-chemical factors (Mahajan, 1981). *Limnocalanus* sp. has been reported to be cold stenotherm and, therefore, confined to cold well-oxygenated waterbodies (Dadswell, 1974). Contrary to this, in the present study, *Limnocalanus* sp. was only found in MP wetland with maximum occurrence in warm condition during June to July, 2001 (Table 17), showing high temperature tolerance. Gannnon and Stenberger (1978) have reported *Diaptomus* sp. as an indicator of eutrophication, whereas Carter (1971) and Patalas (1972) have reported *Diaptomus* sp. inhabiting oligotrophic water bodies. In the present study, *Diaptomus* sp. was always found in abundance throughout the period of investigations in all the wetlands. Mahajan (1981) has reported Diaptomus sp. as very sensitive indicators of pesticidal pollution.

Ostracods are abundant and widely distributed in both standing and running waters. They inhabit all types of substrate, in both standing and running waters, including rooted vegetation, algal mats, debris, mud, sand and rubble. A few species swim about actively above the substrate (Pennak, 1978). Ostracods are comparatively difficult to study from rest of the groups of zooplankton, chiefly because of their somewhat opaque bivalve shell, more accurately, a carapace. Even some of the representatives occur only as commensals or parasites on the gills of cray fishes (Tonapi, 1980).

Superficially, the members of the subclass Ostracoda resemble miniature mussels, and 'mussels shrimps' is an old European vernacular name. However, this name is so easily confused with 'calm shrimps'. The term '*Seed shrimps*' is suggested as an appropriate alternative for ostracods which look much like small seeds (Pennak, 1978).

In size, Indian species ranged from 0.5 to 2.00 mm in length, varying in their colour (Tonapi, 1980). Ostracods can be easily identified from cladocerans by having smaller rather no growth lines on the shell. They have un-segmented body enclosed in two-hinged valves and resemble like tiny clams (Cole, 1983). Most of the fresh water ostracods are bottom dwellers, although some appear occasionally in plankton samples. One truly plankton sample species is *Cypris* sp. (Cole, 1983).

In the present study, ostracods were only found at CP-1 and CP-2 contributing low percentage composition in both the wetlands (Figs. 11, 11a, b). They were never found in any sample of MP. Density of ostracod sp. ranged from 1 to 4 No./L in different months of the study period. Maximum number was noted during August, 2000 and February, 2001 and minimum during January, October and November, 2002 at CP-1 (Table 15). At CP-2, maximum number was noted during November, 2000 and April, 2001 and minimum during July and October, 2001 (Table 16). In both the wetlands, the distribution pattern was found to be very irregular as no definite seasonal maxima and minima were recorded.

The fluctuations recorded in the ostracod density at different wetlands (CP-1 and CP-2) during different months may be due to fluctuations in the temperature, which is regarded as one of the important factors affecting parthenogenesis and their seasonal pattern of reproduction (Wetzel, 1983). Patil and Karikal (2001) have reported maximum population during post- monsoon months followed by very few numbers during early winter indicating their preference to moderate temperature. Kaushik and Sharma (1994) have observed that the ostracods occur in great numbers when the temperature of the water body is around 20 °C, which seems to be moderate and optimum for the growth and production of ostracods. High ostracod density, during monsoon months (August, 2000) and post-monsoon months (November, 2000) may be due to high depth of the water body. Wetzel, (1983) has reported increased reproductive potential with increasing depth.

In the present investigations, *Cypris* sp. contributed the ostracoda group (Table 15 and 16). Regarding their population dynamics they exhibited distinct seasonal periodicity (Wetzel, 1983). Some species exhibit a single generation per year, others two or three.

In conclusion, it can be said that the monthly fluctuations in the density of ostracods may be due to the fluctuations in environmental conditions, like depth, temperature, availability of food and nutrients, and also variations in the predation pressure of the benthic animals. *Cypris* sp. was found to be absent in MP wetland, which is grossly polluted with detergents due to washermen's activity. Pennak (1978) has also reported absence of *Cypris* in grossly polluted waters.

Regarding their significance, they only form a minor element in the diet of young and adult fish (Pennak, 1978). However, Tonapi (1980) reported these organisms forming a very good food for culturable fishes.

***Eggs and Nauplii*:** During the present study, different developmental stages of zooplankton were counted together as eggs and nauplii. Results are given in Tables 15 to 17, and their percentage composition is represented in Figs.11-11b.

Nauplii: During quantitative analysis all the copepodite and nauplier stages were lumped together. Larval morphology is not yet known in most species of copepods. Some adult copepods especially cyclopoids are usually mistaken for adults by the beginners. Hence, it is necessary to differentiate and clearly distinguish an immature individual from its adults (Reddy, 2001).

The copepods eggs hatch into small compact active free-swimming larvae called *nauplii*, which has three pairs of appendages (Pennak, 1978). There are all together six successive nauplier stages, which feed, grow, moult and acquire further appendages (Wetzel, 1983). After sixth naupliur mould, an enlarged and more elongated from, the Ist copepodite *Instar* develops. There are five copepodite stages during which additional appendages and body segments develop. The sixth and final copepodite stage is the adult. The time required to complete the juvenile stage is highly variable among different species and depends upon seasonal conditions (Wetzel, 1983; Reddy, 2001).

In the present investigations, nauplier stages were observed throughout the period of study except during November, 2000 and October, 2001 in CP-1 (Table 15). Only slight differences were observed in the number of nauplii in all the wetlands. This shows that reproduction in copepods is carried out throughout the year. Pennak (1978) also reported reproduction in some species of copepods carried out through out the year having three or more generations. He, however, has also mentioned only one generation in certain species of copepods. In the case of MP wetland, greatest number of nauplii were observed during post-monsoon months (October, November, 2000 and 2001), but never found absent in any month of the study.

***Eggs*:** The number of eggs of rotifers and crustaceans were lumped together and countings were made together during the period of investigations. The results are given in Tables 15 to 17. They also occurred throughout the period of study except in few months, and not much difference was noted in the number of eggs during different months. Hillbritch *et al.* (1988) have reported increased fecundity at high temperature but, here, in the present investigations, no such relationship could be established with temperature (Tables 15 to17). Mirical and Serra (1989) have also reported negligible effect of temperature on fecundity of rotifers. On the other hand, they have also reported salinity as primary factor affecting fecundity on the rotifers. Year round occurrence of eggs also indicate that rotifers are prolific and continuous breeders.

Table 12
Monthly Abundance And Distribution of Phytoplankton Population (No./ml) at CP-1 Wetland.

	Aug. 00	Sep.	Oct.	Nov.	Dec.	Jan. 01	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
MYXOPHYCEAE																	
Microcystis sp.	62	66	47	32	16	15	32	48	62	62	54	50	60	62	46	30	14
Anabaena sp.	4	5	6	4	3	3	6	3	5	7	4	3	3	4	5	3	2
Oscillatoria sp.	1	2	2	3	4	3	3	3	2	6	4	2	1	1	1	2	3
Spirulina sp.	1	–	–	1	–	3	4	2	4	4	–	1	2	–	1	1	1
Total	68	73	55	40	23	24	45	56	73	79	62	56	66	67	53	36	20
CHLOROPHYCEAE																	
Pediastrum sp.	4	3	2	1	4	3	2	5	4	3	2	1	3	2	1	–	3
Crucigenia sp.	9	11	12	9	7	7	10	11	13	16	12	8	7	10	11	8	6
Ankistrodesmus sp.	8	8	3	14	11	13	11	12	11	13	8	7	7	7	2	12	10
Scenedesmus sp.	16	11	8	16	6	7	22	6	9	6	4	5	12	10	7	12	5
Protococcus sp.	14	12	16	18	13	14	15	11	17	18	14	12	12	15	17	12	13
Coelastrum sp.	2	2	1	2	1	1	2	3	3	2	3	1	1	1	–	1	–
Chlorella sp.	2	2	–	2	–	–	2	3	3	2	3	2	–	1	1	–	1
Tetraspora sp.	1	4	3	2	5	1	–	–	11	1	–	1	–	3	2	1	4
Spirogyra sp.	4	1	4	5	3	2	3	3	1	1	2	1	3	–	3	4	2
Ulothrix sp.	3	3	2	4	3	1	–	3	1	–	–	1	2	2	1	3	2
Zygnema sp.	3	3	2	2	–	–	–	2	–	1	1	–	–	2	1	1	1
Microspora sp.	2	2	2	1	2	2	–	–	–	1	1	–	1	1	2	1	2
Total	68	62	55	76	55	51	67	59	73	64	50	39	48	54	48	55	49
DESMIDIACEAE																	
Closterium sp.	7	5	4	3	5	4	3	3	2	5	5	6	4	7	3	4	4
Cosmarium sp.	3	2	4	2	3	2	3	4	2	5	4	3	2	1	3	1	2
Genicularia sp.	2	2	3	3	1	1	4	3	2	2	1	–	1	1	2	2	–
Total	12	9	11	8	9	7	10	10	6	12	10	9	7	9	8	7	6
BACILLARIOPHYCAE																	
Navicula sp.	11	14	16	5	12	17	13	4	15	6	3	4	10	12	15	4	10
Nitzschia sp.	12	13	14	4	7	18	8	3	6	7	4	7	11	12	13	3	6
Synedra sp.	5	8	9	11	8	9	7	4	6	5	4	3	4	7	8	10	7
Cyclotella sp.	3	4	3	2	4	3	4	2	3	4	2	1	2	3	2	1	3
Amphora sp.	3	4	4	4	6	4	4	3	2	3	2	1	2	3	3	2	5
Diatoma sp.	2	3	3	3	4	3	4	2	2	5	3	2	1	2	2	1	3
Total	36	46	49	29	41	54	40	18	34	30	18	18	30	39	43	21	34
EUGLENOPHYCEAE																	
Euglena sp.	8	8	10	10	19	19	9	10	14	5	3	8	7	6	9	10	18
Phacus sp.	10	15	16	17	15	15	8	7	10	8	5	3	9	12	15	16	13
Total	18	23	26	27	34	34	17	17	24	13	8	11	16	18	24	26	31
G. Total	202	213	196	180	162	170	179	160	210	198	148	133	167	187	176	145	140

Table 13

Monthly Abundance And Distribution of Phytoplankton Population (No./ml) at CP-2 Wetland.

	Aug. 00	Sep.	Oct.	Nov.	Dec.	Jan. 01	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
MYXOPHYCEAE																	
Microcystis sp.	10	12	7	6	6	18	25	35	40	45	18	12	11	12	8	7	7
Anabaena sp.	1	1	2	1	2	2	1	2	1	–	–	–	–	–	–	2	1
Oscillatoria sp.	1	3	3	2	1	1	1	–	1	–	–	–	–	1	3	2	1
Spirulina sp.	–	–	–	2	–	–	4	3	7	6	–	–	1	–	2	3	1
Total	12	16	12	11	9	21	31	40	49	51	18	12	12	13	13	14	10
CHLOROPHYCEAE																	
Crucigenia sp.	1	2	3	1	1	10	9	7	4	3	2	1	2	1	3	1	2
Ankistrodesmus sp.	4	3	6	3	3	6	5	5	3	3	2	3	3	2	5	2	2
Scenedesmus sp.	4	4	6	4	2	8	6	4	4	3	2	1	3	3	5	3	1
Protococcus sp.	10	24	16	6	8	22	12	8	18	10	7	6	9	21	12	8	8
Coelastrum sp.	7	6	2	2	–	3	5	6	5	4	3	1	4	2	4	3	2
Chlorella sp.	2	3	2	2	1	3	2	2	2	2	1	1	2	1	2	1	2
Tetraspora sp.	3	2	3	4	2	5	3	6	3	4	2	3	2	4	3	2	2
Spirogyra sp.	1	2	2	1	–	–	–	–	–	–	1	–	–	2	1	1	2
Ulothrix sp.	–	–	–	1	2	1	1	1	–	1	–	–	–	–	1	1	1
Zygnema sp.	–	–	–	–	–	1	1	–	–	–	–	–	–	–	1	–	1
Microspora sp.	–	–	1	1	–	–	–	–	–	–	–	–	–	–	–	1	–
Total	32	46	41	25	19	59	44	39	39	30	20	16	25	36	37	23	23
DESMIDIACEAE																	
Closterium sp.	4	3	2	3	4	5	6	3	4	5	3	2	1	2	1	2	3
Cosmarium sp.	2	2	2	3	2	3	2	3	4	3	2	1	2	1	1	2	2
Genicularia sp.	3	2	3	2	3	3	5	4	3	2	3	2	3	2	2	1	3
Total	9	7	7	8	9	11	13	10	11	10	8	5	6	5	4	5	8
BACILLARIOPHYCAE																	
Navicula sp.	6	4	6	4	4	8	6	10	12	6	5	8	6	4	5	6	4
Nitzschia sp.	5	3	2	2	2	2	3	2	3	4	2	3	4	3	2	4	3
Synedra sp.	4	4	6	4	6	8	4	4	6	8	6	5	4	3	4	5	5
Cyclotella sp.	–	–	1	–	1	1	–	1	–	1	–	1	–	1	–	1	2
Amphora sp.	1	1	–	–	–	1	2	1	–	1	–	–	2	1	–	1	2
Diatoma sp.	–	–	1	2	2	2	1	2	2	1	–	–	–	2	1	2	2
Total	16	12	16	12	15	22	16	20	23	21	13	17	16	14	12	19	18
EUGLENOPHYCEAE																	
Euglena sp.	12	10	10	8	6	8	15	10	12	8	6	5	8	9	9	10	8
Phacus sp.	8	6	7	5	8	12	9	12	10	6	7	6	4	8	9	7	12
Total	20	16	17	13	14	20	24	22	22	14	13	11	12	17	18	17	20
G. Total	89	97	93	69	66	133	128	131	144	126	72	61	71	85	84	78	79

Table 14

Monthly Abundance And Distribution of Phytoplankton Population (No./ml) at MP Wetland.

	Aug. 00	Sep.	Oct.	Nov.	Dec.	Jan. 01	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
MYXOPHYCEAE																	
Microcystis sp.	4	3	4	2	3	7	5	8	6	5	10	3	5	4	5	3	3
Anabaena sp.	12	10	12	4	5	4	5	9	6	6	5	13	16	11	13	5	5
Oscillatoria sp.	1	–	–	1	–	4	2	5	7	1	3	1	1	1	–	–	–
Spirulina sp.	4	3	3	4	2	5	3	5	9	3	8	5	4	4	5	3	2
Nostoc sp.	2	4	2	4	4	3	4	3	4	4	7	2	3	5	3	5	5
Total	23	20	21	15	14	23	19	30	32	19	33	24	29	25	26	16	15
CHLOROPHYCEAE																	
Scenedesmus sp.	2	2	3	4	2	5	3	5	5	11	7	4	3	3	4	5	3
Coelastrum sp.	3	3	4	–	5	6	5	5	6	9	8	3	4	4	5	–	6
Spirogyra sp.	2	–	2	3	–	3	3	4	5	6	4	3	3	–	3	4	–
Zygnema sp.	2	2	2	–	2	3	2	6	6	2	3	2	3	3	3	–	3
Microspora sp.	1	1	1	2	3	4	1	3	3	5	6	2	2	2	2	3	4
Selenastrum sp.	3	2	3	2	2	5	4	7	10	5	5	5	4	3	4	3	3
Total	13	10	15	11	14	26	18	30	35	38	33	19	19	15	21	15	19
DESMIDIACEAE																	
Closterium sp.	2	1	2	1	2	2	2	2	2	1	2	1	2	1	2	–	1
Cosmarium sp.	2	2	1	2	3	4	5	3	2	3	2	1	2	1	–	–	1
Desmidium sp.	1	1	1	2	1	2	1	1	2	2	1	–	1	1	–	2	2
Total	5	4	4	5	6	8	8	6	6	6	5	2	5	3	2	2	4
BACILLARIOPHYCAE																	
Navicula sp.	4	2	5	4	3	6	9	11	9	7	5	5	5	3	6	5	3
Nitzschia sp.	3	4	6	1	1	4	7	7	9	4	4	3	4	5	7	–	2
Synedra sp.	4	3	4	3	3	7	6	8	12	8	6	4	5	4	5	4	4
Cyclotella sp.	2	1	2	2	2	3	2	4	5	4	4	1	3	–	3	3	5
Diatoma sp.	1	1	–	–	1	3	4	2	2	3	2	2	2	2	2	–	–
Total	14	11	17	10	10	23	28	32	37	26	21	15	19	14	23	12	14
EUGLENOPHYCEAE																	
Euglena sp.	8	10	6	8	10	8	6	4	8	6	4	2	8	6	4	4	6
Phacus sp.	4	5	6	4	5	4	3	2	4	3	2	1	4	3	2	2	3
Total	12	15	12	12	15	12	9	6	12	9	6	3	12	9	6	6	9
G. Total	67	60	69	53	59	92	82	104	122	98	98	63	84	66	78	51	61

Table 15

Monthly Abundance And Distribution of Zooplankton Population (No./L) at CP-1 Wetland.

	Aug. 00	Sep.	Oct.	Nov.	Dec.	Jan. 01	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
ROTIFERA																	
Brachionus angularis	4	4	7	5	3	3	2	2	3	4	4	2	4	3	6	4	5
Brachionus calyciflorus	4	6	7	5	3	3	2	2	3	4	4	2	3	5	6	5	3
Keratella tropica	2	1	1	2	2	1	2	1	2	–	–	1	1	1	2	2	2
Filinia sp.	5	4	3	2	3	2	3	3	3	2	6	5	4	3	2	2	3
Testudinella sp.	1	1	–	–	–	–	–	–	–	–	–	–	–	–	1	–	–
Asplanchna sp.	1	–	1	1	2	2	1	2	1	1	–	–	2	1	–	2	2
Lecane sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
Notholca sp.	2	3	2	1	–	–	3	1	3	2	1	3	2	3	2	2	1
Total	19	19	21	16	13	11	13	11	15	13	15	13	16	16	20	17	17
CLADOCERA																	
Daphnia pulex	9	10	16	13	13	16	15	12	16	9	6	5	9	11	15	12	12
Daphnia parvula	2	6	5	7	3	4	1	1	1	1	–	–	2	4	3	6	3
Daphnia carinata	2	4	5	7	3	3	1	1	2	1	2	1	–	1	2	4	3
Daphnia magna	11	16	13	13	16	15	11	16	9	6	5	8	10	12	11	12	11
Ceriodaphnia sp.	4	3	2	3	3	2	3	2	3	2	2	2	1	2	3	1	2
Moina sp.	5	5	4	5	3	4	4	3	4	2	1	1	2	1	2	2	3
Diaphanosoma sp.	4	5	4	3	5	6	5	6	4	3	2	2	3	4	3	4	5
Simocephalus sp.	3	4	3	4	4	3	4	3	4	2	3	1	–	2	3	2	3
Alonella sp.	1	–	2	1	2	1	3	2	2	–	–	–	–	–	–	2	1
Leptodora sp.	2	2	1	2	3	1	2	3	2	1	–	–	1	1	–	1	2
Total	43	55	51	58	55	55	49	49	47	27	21	20	28	38	42	46	45
COPEPODA																	
Cyclops sp.	11	12	13	11	9	2	12	12	15	9	6	7	10	11	12	10	8
Canthocamptus sp.	4	3	2	2	1	3	4	–	–	1	–	–	3	2	1	1	1
Diaptomus sp.	7	13	9	11	8	11	13	9	7	4	3	5	6	12	8	10	9
Total	22	28	24	24	18	16	29	21	22	14	9	12	19	25	21	21	18
OSTRACODA																	
Cypris sp.	4	3	2	2	3	1	4	3	2	3	2	2	3	2	1	1	2
EGGS	1	2	1	1	2	1	2	1	1	3	2	1	–	1	2	1	1
NAUPLII	3	2	1	–	2	3	1	2	3	1	1	1	2	1	–	1	1
G. Total	92	109	100	101	93	87	98	87	90	61	50	49	68	83	85	87	84

Table 16

Monthly Abundance And Distribution of Zooplankton Population (No./L) at CP-2 Wetland.

	Aug. 00	Sep.	Oct.	Nov.	Dec.	Jan. 01	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
ROTIFERA																	
Brachionus angularis	2	1	1	1	2	2	4	3	3	3	2	1	2	2	4	3	2
Brachionus calyciflorus	3	3	5	4	2	2	2	–	1	2	1	–	2	2	3	3	1
Notholca sp.	–	–	–	2	3	–	–	1	2	1	–	–	–	1	1	2	1
Keratella sp.	–	–	1	–	2	–	1	–	–	–	–	1	–	–	1	2	2
Filinia sp.	4	3	4	6	8	3	2	4	1	2	3	3	2	2	3	5	6
Total	9	7	11	13	17	7	9	8	7	8	6	5	6	7	12	15	12
CLADOCERA																	
Daphnia pulex	7	6	6	5	9	7	4	3	2	1	5	4	5	4	8	6	3
Daphnia magna	11	12	10	11	13	12	5	4	2	4	3	4	7	10	9	8	11
Daphnia carinata	–	–	1	3	5	4	3	–	3	–	1	2	–	1	1	2	4
Moina sp.	3	3	2	3	6	3	3	4	2	1	1	2	2	2	3	4	5
Ceriodaphnia sp.	–	–	3	3	2	3	1	–	1	1	–	–	–	–	2	2	1
Simocephalus sp.	–	–	–	–	–	1	2	–	3	1	–	–	–	–	–	1	2
Alonella sp.	–	–	–	–	–	1	–	–	1	–	–	–	–	–	–	1	1
Leptodora sp.	–	–	3	2	3	2	3	2	1	–	–	–	1	–	–	2	2
Total	21	21	25	27	38	33	21	13	15	8	10	12	15	17	23	26	29
COPE PODA																	
Cyclops sp.	15	20	21	22	30	22	12	15	5	3	4	12	12	18	20	21	25
Canthocamptus sp.	2	2	3	2	1	2	3	2	2	1	2	3	1	1	2	2	2
Diaptomus sp.	10	9	8	8	8	7	5	10	10	6	4	5	8	8	7	6	5
Total	27	31	32	32	39	31	20	27	17	10	10	20	21	27	29	29	32
OSTRACODA																	
Cypris	3	3	2	4	3	2	3	3	4	2	1	3	2	2	1	2	3
EGGS	–	–	–	2	1	–	1	–	1	–	1	2	2	1	1	2	1
NAUPLII	1	2	2	1	2	3	1	2	1	1	2	2	1	2	1	1	2
G. Total	61	62	62	79	100	76	55	53	45	29	30	42	47	56	67	75	78

Table 17
Monthly Abundance And Distribution of Zooplankton Population (No./L) at MP Wetland.

	Aug. 00	Sep.	Oct.	Nov.	Dec.	Jan. 01	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
ROTIFERA																	
Brachionus calyciflorus	6	10	2	4	8	6	7	6	2	4	9	6	5	7	5	4	3
***Rotaria* sp.**	2	3	4	12	1	1	–	–	–	1	2	1	–	2	3	6	1
***Keratella* sp.**	–	4	2	1	6	2	1	–	–	1	–	–	–	2	3	8	4
***Filinia* sp.**	10	4	5	3	5	4	5	5	7	12	16	25	28	18	16	8	4
***Notholca* sp.**	4	3	3	2	1	–	1	1	–	1	1	1	3	2	1	2	1
Total	22	24	16	22	21	13	14	12	9	19	28	33	36	31	28	28	13
CLADOCERA																	
Daphnia pulex	12	10	15	13	13	10	8	20	25	15	10	14	18	22	27	25	21
***Ceriodaphnia* sp.**	1	1	–	–	–	–	–	–	–	–	–	–	3	5	–	–	–
***Moina* sp.**	3	2	4	2	3	–	5	5	7	3	2	4	2	5	9	7	2
***Simocephalus* sp.**	6	7	8	8	9	4	5	6	7	4	5	4	6	6	7	7	8
***Bosmina* sp.**	1	2	1	–	–	–	1	–	–	–	–	–	3	4	2	1	1
Total	23	22	28	23	25	14	19	31	39	22	17	22	32	42	45	40	32
COPEPODA																	
***Cyclops* sp.**	15	18	13	10	8	3	4	11	9	11	17	22	18	22	11	12	11
***Canthocamptus* sp.**	–	–	–	–	–	–	2	–	1	–	2	5	–	–	–	1	–
***Diaptomus* sp.**	7	13	5	6	4	8	4	6	8	10	13	15	14	15	10	2	3
***Limnocalanus* sp.**	3	4	2	2	3	2	4	2	3	1	8	13	4	3	4	1	2
Total	25	35	20	18	15	13	14	19	21	22	40	55	36	40	25	16	16
EGGS	5	4	5	3	8	5	2	3	2	4	6	6	10	5	4	4	3
NAUPLII	5	6	13	12	8	6	7	3	4	5	6	7	11	15	10	6	5
G. Total	80	91	82	78	77	51	56	68	75	72	97	123	125	133	112	94	69

Table 17a
Monthly variations in Total Zooplankton (No./L) and Total Phytoplankton (No./ml) in Wetlands.

Months ↓	Total Zooplankton			Total Phytoplankton		
Wetlands →	CP-1	CP-2	MP	CP-1	CP-2	MP
August, 2000	91	61	80	202	89	67
September	108	62	91	213	97	60
October	100	62	82	196	93	69
November	101	79	78	180	69	53
December	93	100	77	162	66	59
January, 2001	87	76	51	170	133	92
February	98	55	56	179	128	82
March	87	53	68	160	131	104
April	90	45	75	210	144	122
May	61	29	72	198	126	98
June	50	30	97	148	72	98
July	49	42	123	133	61	63
August	68	47	125	167	71	84
September	83	56	133	187	85	146
October	84	67	112	176	84	78
November	87	75	94	145	78	51
December	83	78	69	140	79	61

CP-1: Chharat Pond 1; CP-2: Chharat Pond 2; MP: Medical Pond

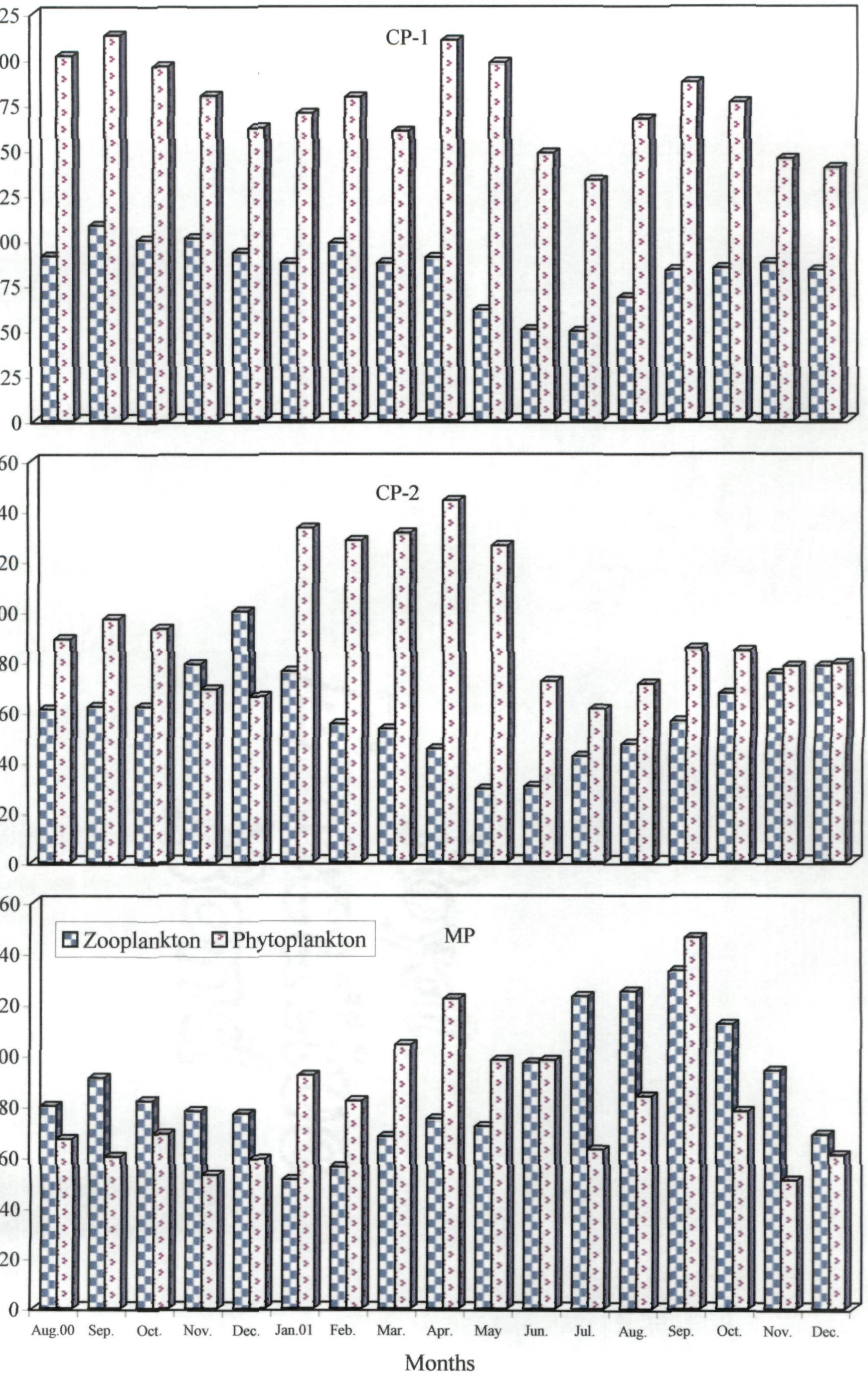

Fig. 9. Monthly variations in Total Zooplankton (No./L) and Phytoplankton (No./ml) populations at CP-1, CP-2 and MP Wetlands.

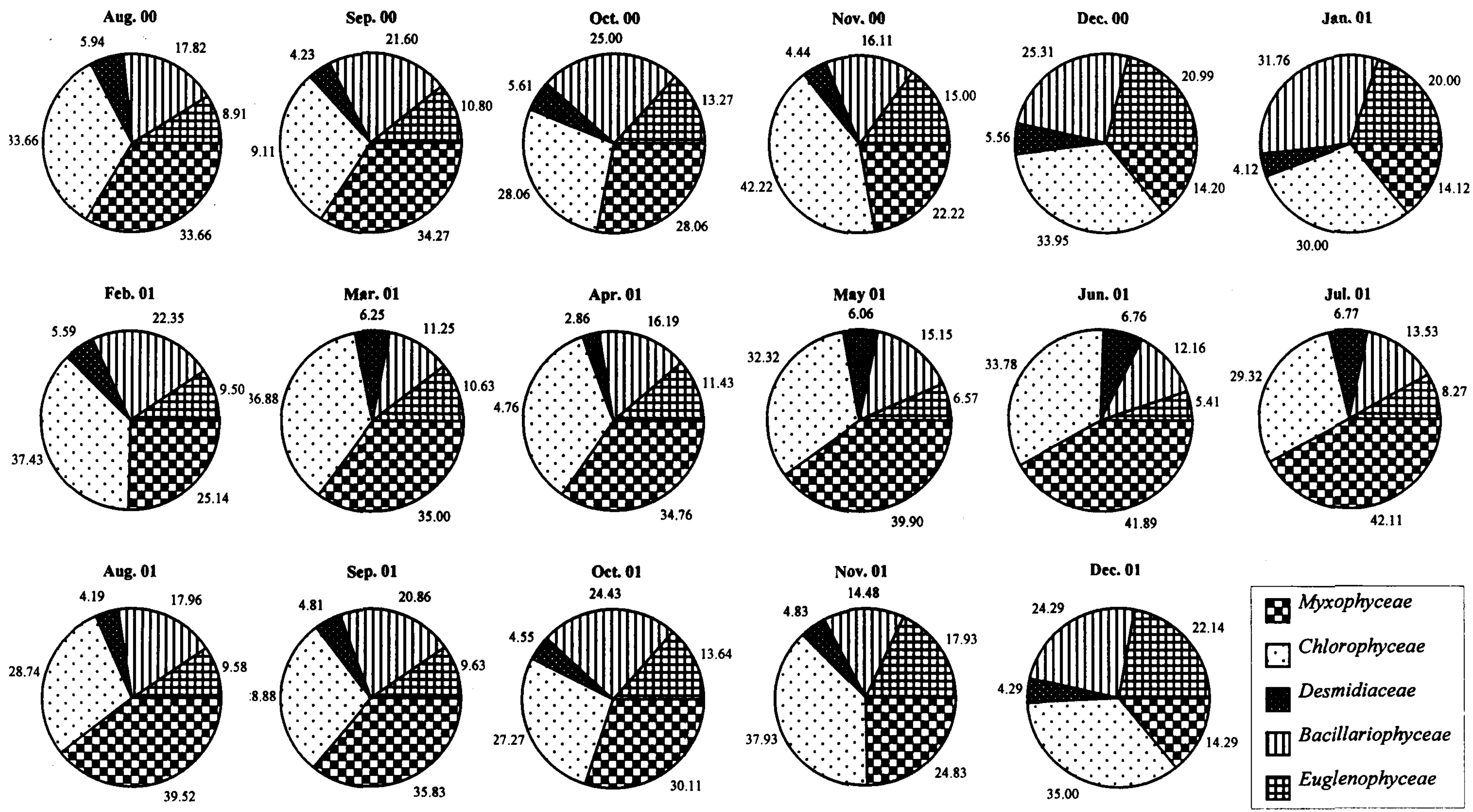

Fig. 10. Percent Composition of Different Groups of Phytoplankton at CP-1 Wetland.

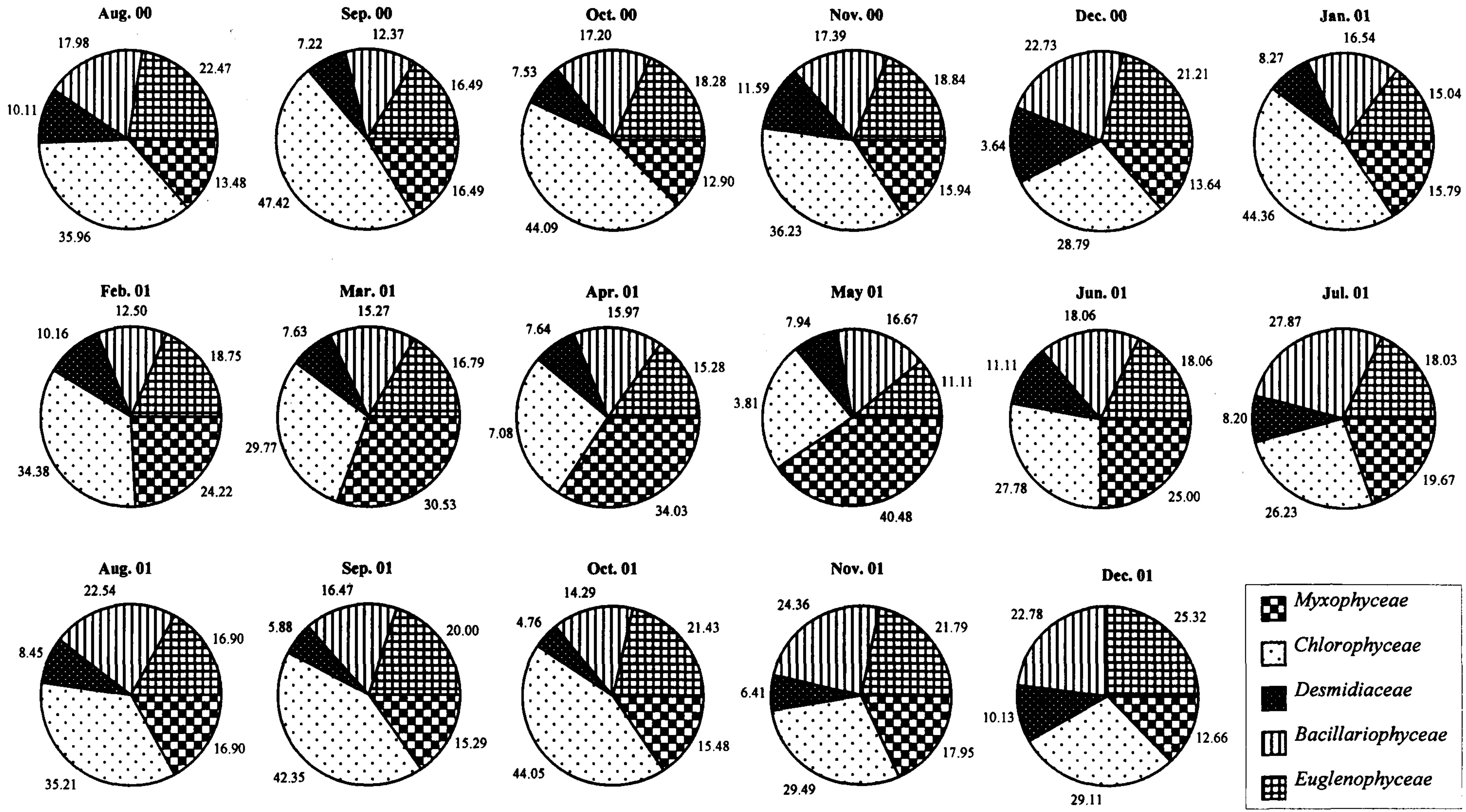

Fig. 10a. Percent Composition of Different Groups of Phytoplankton at CP-2 Wetland.

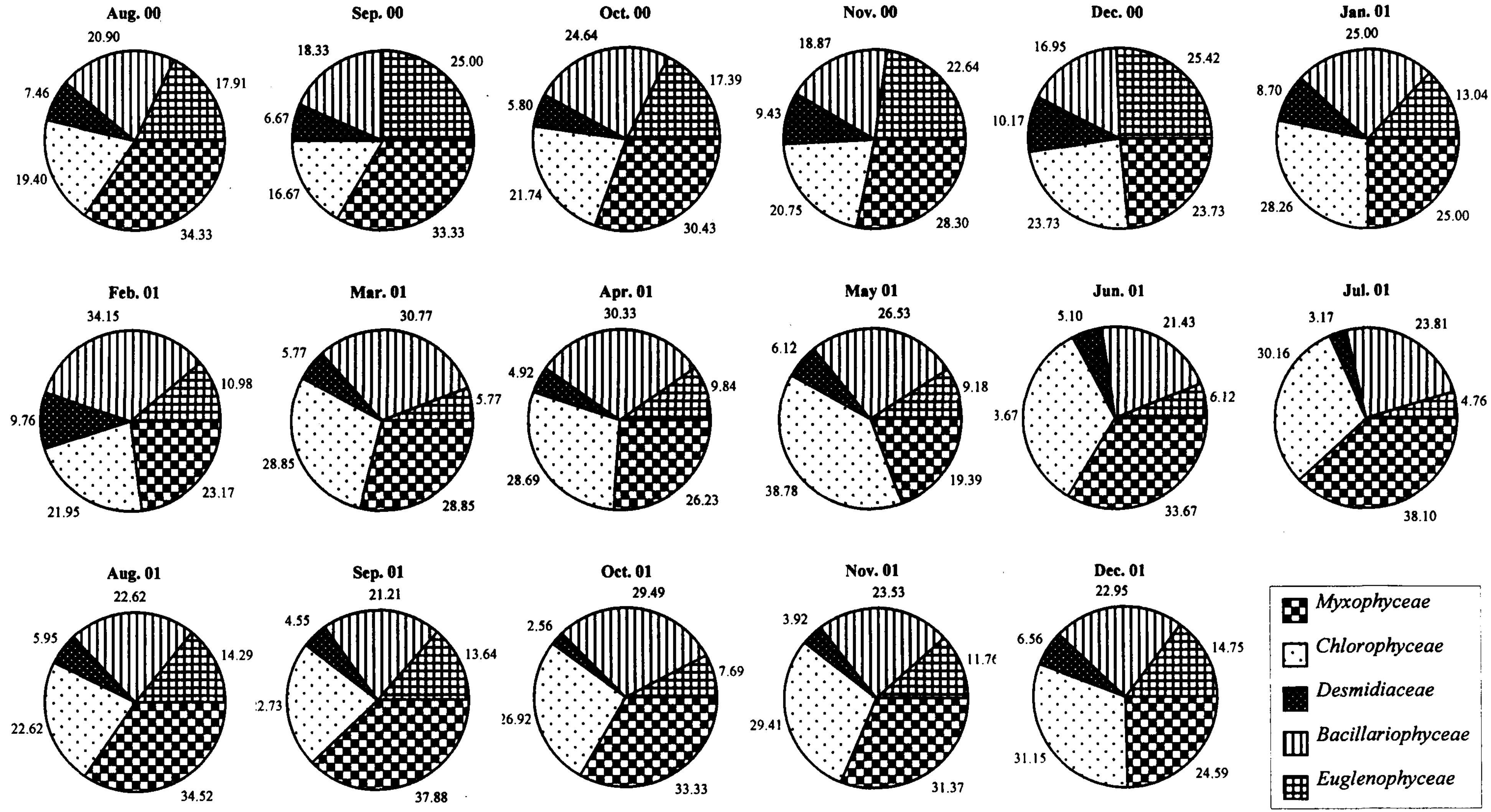

Fig. 10b. Percent Composition of Different Groups of Phytoplankton at MP Wetland.

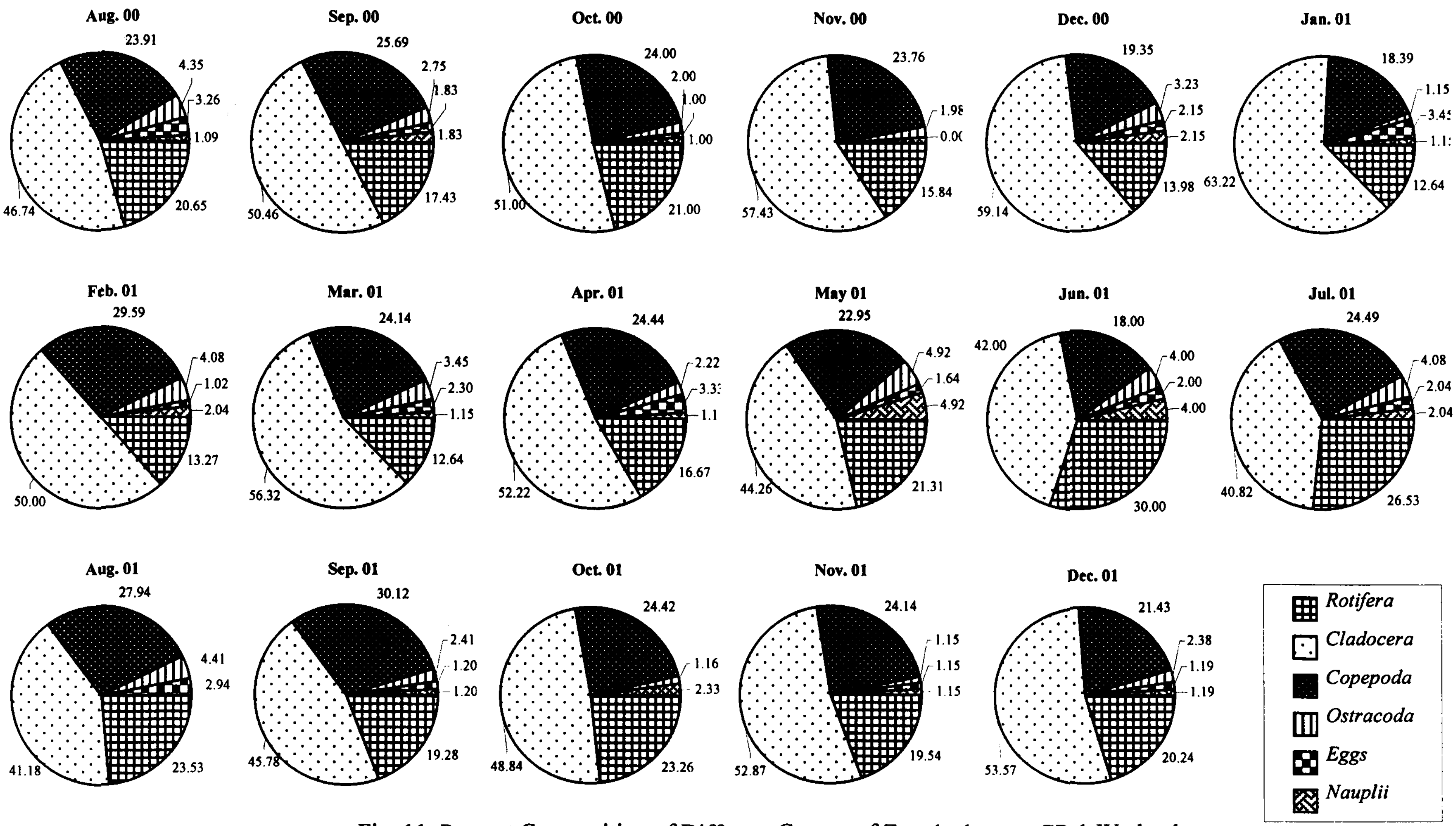

Fig. 11. Percent Composition of Different Groups of Zooplankton at CP-1 Wetland.

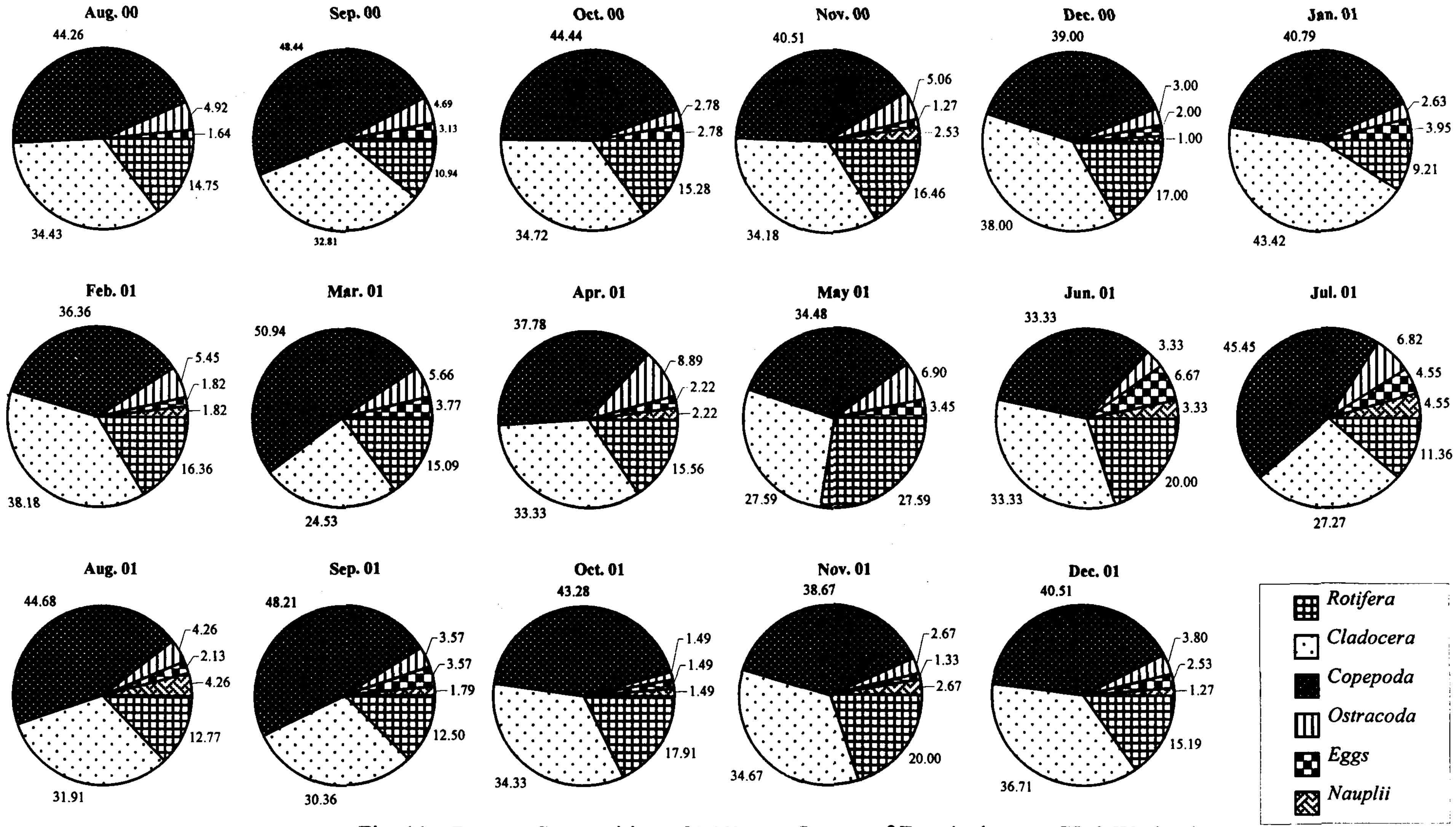

Fig. 11a. Percent Composition of Different Groups of Zooplankton at CP-2 Wetland.

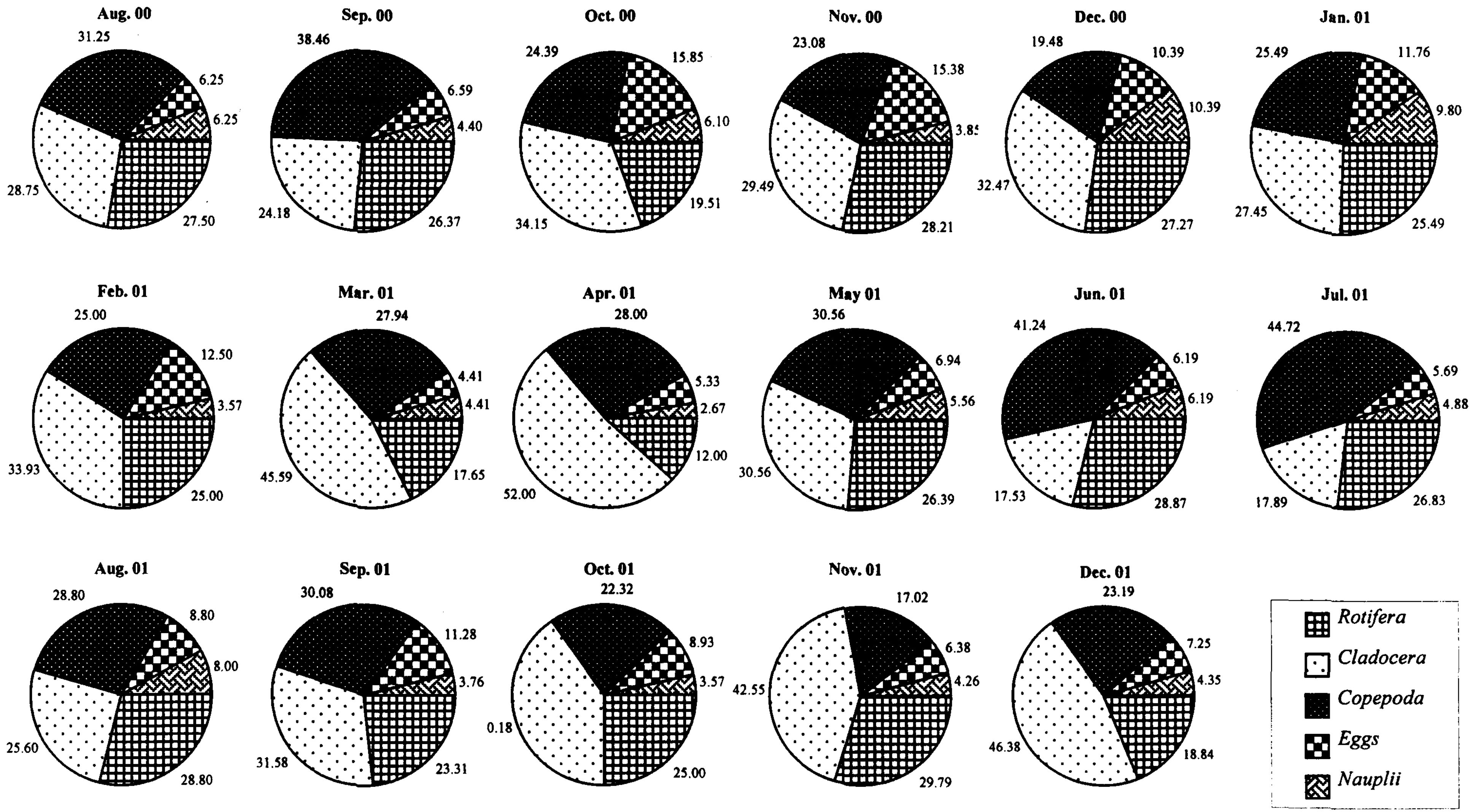

Fig. 11b. Percent Composition of Different Groups of Zooplankton at MP Wetland

(ii) – OTHER AQUATIC BIOTA

Besides plankton, which constitutes the biological communities in an aquatic system, many *aquatic macrophytes*, *fishes*, *amphibians* and *insects* were also encountered during the present investigations on these wetlands.

Aquatic Macrophytes: The term aquatic macrophyte, is commonly used to the macroscopic forms of aquatic vegetation including macro-algae. These macrophytes were found commonly at CP-1 and CP-2. Littoral regions of freshwater ecosystems are commonly, intensely and metabolically active zone owing to the presence of aquatic macrophytes (Wetzel, 1983). These macrophytes are considered to be the primary source of organic matter to freshwaters. The synthesis of organic matter by aquatic vegetation and its decomposition in wetland sediments result in high loading of dissolved organic matter and inorganic nutrients to recipient lakes.

On the basis of their growth habits in relation to the water surface, they have been divided into *submerged weeds*, *surface weeds* and *emergent* or *marginal weeds.*

Among ***submerged weeds***, certain higher algae, like *Chara, Ulothrox, Spirogyra* and *Hydrodictyon,* were quite common in these wetlands. Since the wetlands, under study, were not much deeper, such species were commonly encountered.

Besides these weedy fresh water algae, other species of submerged macrophytes, which are commonly encountered in these wetlands, include members of *Potamogetonanceae, Hydrocharitaceae, Najadaceae, Hallorhagaceae, Salviniaceae, Pontederiaceae, Hydrocaryaceae, Alismaceae, Typhaceae and Juncaceae* families. Following species have been observed in the wetlands under study,

Potamogeton crispus, called as *curly leaf pondweed*, is completely submerged macrophyte and restricted chiefly to shallow waters.

Hydrilla verticillata, called as *hydrilla*, is about 11-13 mm long and submerged species. Flowers arising singularly from terminal spathe near the water surface.

Elodea canadensis, called as common *elodea,* is about 40-45 mm long. Flowers solitary, auxillary and dioecious.

Myriophyllum spicatum, called as *Eurasian milfoil*, is solely submerged having spikes raised 5-10 cm above water level.

Valilisneria Americana, is called as *water celery* or *eelgrass*, is a submerged perennial with creeping rootstocks. This is restricted to slow moving or still water bodies.

Among ***floating macrophytes***, *Salvina auriculata*, *Azolla caroliniana*, *Eichhornia crassipes*, and *Lemna minor* were common in these wetlands.

Salvina auriculata, called as *water fren*, is a root less plant with floating leaves. It is about 3-4 cm long with three leaves, two of three leaves are floating and third one is submerged. Submerged one is modified into root like structure.

Azolla caroliniana, called as *water velvet*, is a floating fern with 2-3mm wide green leaves banded together in a scale like manner. Plants turning blood-red *on* maturity. They were found only in certain months during the study.

Eichhornia crassipes, called as *water hyacinth*, is a perennial, free-floating plant. Its leaves are pea green. A mass of fine fibrous roots hangs in the water from the nodes of each plant. These plants multiply fast, resulting dense, and tough mat on the water surface. They commonly occur in these wetlands, but also regularly removed manually by the villagers and washermen.

Lemna minor, commonly called as *duckweed*, was also found in certain seasons. Fronds about 4 mm long with single underside root.

Among ***marginal emergent aquatic weeds***, *Sagittaria* spp. and *Typha* spp. are commonly found in these wetlands.

Sagittaria spp., commonly called as *arrowheads*, is a shallow water marginal and emergent plant. It commonly occurs in swamps, shallow waters and drainage ditches.

Typha sp., called as *cat tails*, are some of the worst spread weed species in the country. They invade vast swampy areas, wetlands, ditch-banks, and drainage, seepage and flood control channels, even low discharge canals have not been spared.

They are perennial, 2-4m tall, robust grass like emergent plants with joint less stems having 15-30 cm long and 2-3 cm diameter cylindrical spikes. The spike resembles tail of a cat and so the name. They have also been found in these wetlands.

They are capable of absorbing dissolved salts through their entire exposed surface (Gupta, 1972). Aquatic macrophytes are also menace to fish and fisheries, when their growth is excessive, be it emergent, floating or submerged type. The disadvantages caused are many. On the other hand their moderate growth is not only useful but necessary for pond productivity (Srivastava, 2000).

Fish fauna: Fish are often neglected by limnologist despite their commercial value and ecological importance at the apex of most aquatic food webs. They possess great diversities in their habitat and habits (Goldman and Horne, 1983). Fresh water fishes constitute the most conspicuous component of inland aquatic fauna. They exist and occur in all kinds of hydrographic media. In such a vast country like India, they have been recorded and described with different adaptations to manifold climate tracts (Tonapi, 1980). Fish are an integral component of fresh water ecosystems and feed on variety of food organisms, from small to large size and have marked effect on plankton composition and productivity. This fact influences the species composition of phytoplankton and consequently productivity at primary level (Wetzel, 1983).

Certain fish, such as carps, have omnivorous feeding habits and can be very effective in modifying the littoral substrata to the point where many submerged macrophytes are eliminated. Such feeding activities disturbs the sediments and increase turbidity resulting in decline of phytoplankton productivity and transparency.

The commonly occurring fish species in the present wetlands are *Channa punctatus*, *Wallago attu*, *Catla catla*, *Cirrhina mirgala*, *Labeo rohita*, *Colisa fasciatus*, *Esomus danricus*, *Clarias batrachus*, *Heteropneustes fossilis*, *Puntius sophore* and *Gambusia affinis.*

All these species showed wide variations in their population density as observed by the local fishermen and the anglers who use these wetlands for their earnings and recreation purposes respectively.

Insects: The insects comprise more than 75% of all the described animal species and are an extremely successful group. Yet only 3% are aquatic or have aquatic larval stages, and of these only a few hundred are marine or inter-tidal (Cheng, 1976). Most of the aquatic insects have piercing and sucking type of mouth parts. Aquatic insects are often preyed upon by some species of fishes. On the contrary, certain insects and nymphs are voracious feeders and act as predator on fry, fingerlings, small fishes, immature and mature crustaceans, molluscs and several other economically useful organisms (Tonapi, 1980).

The commonly found insects in the present investigations in these wetlands are members of the families, *Ephemeroptera*, *Hebridae*, *Hydrometridae*, *Salididae*, *Notonectidae*, *Nepidae*, *Corixidae*, *Dytiscidae*, *Hydophilidae*, *Tendipediae* and *Syrphidae*.

Ephemeroptera: This group is represented by the *Baetis* sp. They are also called as *may flies*. These are delicate forms of insects found in the vicinity of streams, ponds, lakes, wetlands and rivers. Nymphs of *mayflies* generally inhabit quite waters, like those of present wetlands. They rest on the substratum and are found in abundance during monsoon and post- monsoon months in all the three wetlands. They are herbivorous and form a good food for birds and certain omnivorous fishes.

Hebridae: This group includes velvet *water bugs*. *Hebrus* sp. is a common representative of this group in these wetlands. It is most abundant in the post-monsoon and post-winter months at moderate temperature in all these wetlands. These insects are abundant on the margins of ponds, tanks, canals and wetlands.

Hemiptera (*aquatic bugs*): They are also called as *true bugs* and are essentially terrestrial, few are semi aquatic and a very few species have adapted to submerged conditions. Few species of hemipterans are truly aquatic. They are found on the surface of waters in these wetlands during post-monsoon and post-winter months.

Notonectidae: They are also called as *back swimmers*. They are abundantly found in all the three wetlands, particularly during rainy seasons. They are harmful to carp fry, which they kill in large quantities (Srivastava, 2000). They prefer the still waters.

Nepidae: These insects resemble scorpions and hence called as *water scorpions*. They are found clinging and crawling to the various submerged aquatic plants. *Ranatra* sp. is a common inhabitant at the bottom of these wetlands. Though these insects posses wings but they rarely ever fly. They prey on *daphinds* and other small arthropods.

Other species of the insects which are rarely observed in these wetlands include *Corixa* sp., *Salda* sp., *Cybister* sp., *Steronolophus* sp. and *Tendipes* sp. were also found either in their larval stages or growing stages in these wetlands. They show their abundance during post-monsoon and some post-winter months, but disappear during extreme temperature conditions. Most of these insect species were found in muddy habitats.

The characteristics of the insects are well known and no attempt is made here to summarize the group differences except to point out their presence or absence in different seasons during the present investigations. Some of the insects are known to be as indicator of water chemistry and pollution (Thorpe and Lloyd, 1999). Gibbins *et al.* (2000) have reported members of family Corixidae as potential indicator of changes in the river ecology.

As already mentioned in the Chapter II, these wetlands are also inhabited by amphibians (*Frogs* and *Toads*), *Water snakes*, *Nematodes*, *Worms*, *Ducks* and *Tortoises*.

(iii) – PRIMARY PRODUCTION

The inland freshwater ecosystems of India harbour a rich wealth of primary producers both microphytes and macrophytes which constitute a significant position in trophic level of aquatic system. Biological productivity of any habitat depends largely on its ability to support the growth of photo-autotrophic organisms consisting mainly of higher plants and algae (Kumari and Kumar, 2002).

An accurate knowledge of primary production in natural water body is central concern of limnology (Schwoerbel, 1987). Primary production studies are of paramount interest in understanding eutrophic nature, nutrient status and standing crop of any water body. Sun is the ultimate source of life and eminent driving force of biosphere. Its energy is trapped by chlorophyll bearing plants, which transform it into chemical energy. It is stored by the green plants in the form of plant tissues and called as primary productivity. Thus, the primary productivity is the basis of whole metabolic cycle in natural aquatic ecosystems. The organic matter synthesized during the primary productivity by primary producers is utilised by the consumers inhabiting the system. Thus a pyramid of energy is formed from primary producers, forming the first level, to various consumers and the decomposers in the last. It is one of the most important parameters as far as limnological and fisheries studies are concerned. Based on production potentialities, water bodies can be categorised as *oligotrophic*, *mesotrophic*, *eutrophic* and *dystrophic* (Goldman and Horne, 1983).

Primary production has been used as a potential index of productivity of a given aquatic ecosystem (Wetzel, 1964). Many workers have correlated nutrients available in determining the trophic status of a water body. It is well known that these nutrients help in the synthesis of chlorophyll and act as carrier of essential substances. It becomes necessary in limnological studies to estimate the amount of major nutrients and their role in determing the aquatic primary productivity (Paul and Verma, 1999). A deficiency or excess of these nutrients leads to destruction of the healthy status of the water body. A considerable work has been done in this regard so far. Mortimer (1939) attempted for the first time, the estimation of nitrogen in large water bodies to assess productivity. Schelske *et al.* (1971) studied enrichment of nutrients in relation to chlorophyll levels. David and Robert (1979) reported role of phosphorus compounds in eutrophication, whereas Ferris and Tyler (1985) documented relationship between chlorophyll and phosphorus. Comita (1985) reported seasonal cycles of primary production. Besides, important contributions made on the primary productivity in Indian freshwaters are those of Sreenivasan (1964, 1965, 1970, 1972, 1974), Wetzel (1964, 1966, 1983), Hussainy (1967) Ganapati and Srinivasan (1970, 1972), Khan and Siddiqui, (1971), Khan and Zutshi (1979, 1980), Dutta *et al.* (1984), Wanganeo (1984), Khan *et al.* (1988) and Bohra and Kumar (2002). Work done on primary production outside India include those of Welch (1952), Lund (1965), Wetzel (1964, 1966, 1983), Talling (1965), Brock and Brock (1968), Vollenweider (1969), Odum (1971), Goldman (1972), Brylinsky (1980), Westlake *et al.* (1980), Goldman and Gilbert (1983), Goldman and Horne (1983), Comita (1985), Czernas (1991, 2001), Welch (1992) and Malone *et al.* (1996).

High rates of production both in natural and artificial ecosystems occur when physico-chemical factors are favourable. Biological production is the key to the extent to which natural water resources may be utilized for whatever purpose (Bohra and Kumar, 2002).

Due to galloping increase of population in India, fish production in wetlands and ponds is gaining importance to combat and fulfil the animal protein. This demand can only be fulfilled by increasing the fish production in several unutilised wetlands and other fresh water habitats with diverse geological and climatic features. This can be achieved only by increasing the primary production of these unutilised wetlands as it forms the basis of increasing production at the next level.

The present study gives an account of primary production in three tropical wetlands of Aligarh which have been left untouched so far. These can be used for culturing fish after making proper production studies. The study of primary production include ***gross primary productivity*** (G.P.P.), *the rate of transformation of radiant energy to chemical and is the total production* (i.e. production as well respiration), ***net primary productivity*** (N.P.P.), *the net production left after expenditure in respiration*, and ***community respiration*** (C.R.), *the rate of loss of fixed energy in respiration.* Organic matter is accumulated when G.P.P. exceeds C.R. and therefore, N.P.P. can also be used as an index of secondary productivity (Brylinsky, 1980).

METHODOLOGY

Studies were made at monthly basis on three wetlands namely CP-1, CP-2 and MP. Primary production was estimated by measuring the changes in dissolved oxygen (D.O.) concentration in light and dark bottles after following methodology of Gaarder and Gran (1927) and described by Strickland and Parsons (1972) and Vollenweider (1969). D.O. was determined in the field itself using Winkler's modified technique as described by APHA (1992). Chlorophyll was estimated after following methodology given by Trivedy and Goel (1984).

RESULTS

Wide range of fluctuations were noted in the *net and gross primary production* along with *community respiration* and *chlorophyll 'a'* content. The values are shown in Table 18.

At CP-1, the values of *net primary production*, N.P.P. were found to vary between 0.6870 g C/m^3/hr as noted in January, 2001 and 1.7320 g C/m^3/hr recorded in November, 2001. At CP-2, the N.P.P varied from 0.5640 g C/m^3/hr in January, 2001 to 1.6660 g C/m^3/hr in the month of August, 2001, and at MP, it varied from 0.5640 g C/m^3/hr in February, 2001 to 1.8360 g C/m^3/hr in July, 2001.

The monthly observations of *gross primary productivity* (G.P.P.), showed temporal fluctuations. At CP-1, the values of G.P.P. were found to vary from 0.8230 gC/m^3/hr (January, 2001) to 2.1300 g C/m^3/hr (June, 2001). At CP-2, the G.P.P. values varied between 0.7260 g C/m^3/hr (January, 2001) to 1.9530 g C/m^3/hr (November, 2001), whereas in the case of MP, the G.P.P. values were found to vary between 0.6750 g C/m^3/hr in February, 2001 and 2.2400 g C/m^3/hr in July, 2001.

Community respiration (C.R.) rates were also found to fluctuate in all the three wetlands in different months (Table 18). At CP-1, it varied from 0.0470 gC/m^3/hr in March, 2000 to 0.4050 gC/m^3/hr in June, 2001. At CP -2, the range of C.R. varied from 0.0081 gC/m^3/hr in December, 2000 to 0.9260 gC/m^3/hr in June, 2001 and in the case of MP, C.R. showed variations from 0.0110 $gC/m^3/hr$ (November, 2001) to 0.6781 $gC/m^3/hr$ (August, 2000).

Similarly, variations in Chlorophyll 'a' pigment content have been noted from at all the three wetlands under study showing variations from 0.562 mg/L in February, 2001 to 3.262 mg/L in October, 2000 at CP-1; 0.7220 mg/L in January, 2001 to 3.2410 mg/L in August, 2000 at CP-2; and in the case of MP variations have been recorded from 0.7860 mg/L in February, 2001 to 3.7951 mg/L in October, 2001 at MP.

DISCUSSION

The primary production involves chaemo-autotrophic processes, forming the base of energy flow in the ecosystem. In the present study, *Gross Primary Productivity, Net Primary Productivity* and *Community Respiration* are more or less similar at CP-1, CP-2 and MP. Seasonal fluctuations in the rate of primary production, in these wetlands, were recorded. It appears, therefore, that the production rate does not remain same throughout the year as reported by other workers in tropical waters (Hulbert *et al.*, 1960; Menzel and Ryther, 1961; Prasad and Nair, 1963; Ali and Khan, 1979).

As it is clear from the Table 18, the values of gross primary production were always found higher than the values of net primary production. It was due to the fact that phytoplankton cells lose an appreciable amount of assimilated carbon during different metabolic activities particularly through respiration and excretion (Ryther, 1956; Fogg *et al.*, 1973 and Haque, 1991). A large population under unfavourable conditions may have a low rate of production, whereas a small population under favourable condition may have high rate of production (Bohra and Kumar, 2002).

In the present investigations bimodal fluctuations were recorded in the *primary productivity* showing peaks of higher rates of *N.P.P.* during summer, and post-monsoon seasons at all the three wetlands except at MP where it showed peaks during summer, monsoon, and post-monsoon periods. The variations in the rates of production as noted might be due to favourable and unfavourable physico-chemical conditions during different months of observation. Higher rates indicate that these wetlands are primarily rich in nutrients with enough lighted zone and energy content.

The maximum rate of N.P.P. during summer was probably due to high temperature and appreciable phytoplankton density. Prasad and Nair (1963), Khan and Siddiqui (1971) and Gaur (1998) have reported higher value during summer and at the time of good phytoplankton production. Higher values during some months of post-monsoon and monsoon, in the present study, were found to be due to increased concentration of nutrients added to these wetlands along with the sewage and surface run-off. Sreenivasan (1964) and Ayyappan and Gupta (1985) have also reported high rate of primary production during summer and monsoon months. Low values during the winter months might be due to low temperature, less photoperiod and low intensity of light due to dense fog.

The photosynthetic rate of phytoplankton and other green algae has been reported to be maximum at some intensity between the extremes of mid-day irradiance at the surface (Lewis Jr., 1974). When statistically analysed, G.P.P. and N.P.P. values were found to have a significant positive relationship with Chlorophyll 'a'(Fig. 25) and water temperature (Table 19), at all the three wetlands but with phytoplankton, it showed a non-significant positive correlation at CP-1 and negative at CP - 2 and MP (Table 19).

Community Respiration (C.R.): C.R., the rate of plankton respiration was also estimated in terms of $gC/m^3/hr$. The values of C.R. were found to vary from season to season and from one wetland to another. It did not show any relationship with planktonic organisms in all the three wetlands. It may be because of high rate of decomposition of organic matter in these wetlands and some turbid conditions during different months.

Chlorophyll 'a': Looking at the variation in Chlorophyll 'a' readings at the three studied wetlands, it was found that the Chlorophyll 'a', which is a measure of standing crop of phytoplankton, Welch, 1952) showed wide fluctuations (Table 18).

The spatial variations in the values of Chlorophyll 'a' showed almost the same trend as exhibited by N.P.P. Neilsen and Jensen (1957) and Hutchinson (1975c) considered transparency as an index of productivity, and according to Clarke (1941) the availability, extent and intensity of light are the important factors governing the photosynthetic activity of chlorophyll bearing organisms. High values of Chlorophyll 'a' occurred when transparency was low and vice-versa. The high values of G.P.P. and N.P.P. were obtained at the time of high concentration of Chlorophyll 'a' and vice-versa. A correlation analysis also showed significant direct relationship between Chlorophyll 'a' and G.P.P. and N.P.P. (Table 19 and Fig. 25).

Table 18

Monthly variations in Primary Productivity, Community Respiration and Chlorophyll 'a' in Wetlands.

Months↓ Wetlands →	**Net Primary Productivity ($g\ C/m^3/hr$)**			**Gross Primary Productivity ($g\ C/m^3/hr$)**			**Community Respiration ($g\ C/m^3/hr$)**			**Chlorophyll 'a' (mg pigment/L)**		
	CP-1	**CP-2**	**MP**	**CP-1**	**CP-2**	**MP**	**CP-1**	**CP-2**	**MP**	**CP-1**	**CP-2**	**MP**
August, 2000	1.628	1.567	1.437	1.717	1.806	2.115	0.089	0.239	0.678	2.452	3.241	3.317
September	1.329	1.367	1.322	1.492	1.511	1.473	0.163	0.149	0.151	2.708	2.591	2.683
October	1.482	1.482	1.472	1.693	1.514	1.561	0.211	0.032	0.089	3.262	2.816	3.685
November	1.632	1.371	1.622	1.952	1.731	1.734	0.320	0.360	0.112	3.252	2.146	2.945
December	1.121	1.453	1.351	1.242	1.461	1.442	0.121	0.008	0.091	1.348	2.322	2.545
January, 2001	0.687	0.564	0.892	0.823	0.726	1.064	0.136	0.162	0.172	0.831	0.722	2.075
February	0.923	0.675	0.564	1.023	0.783	0.675	0.100	0.108	0.111	0.562	0.892	0.786
March	1.372	1.264	1.320	1.419	1.375	1.421	0.047	0.111	0.101	2.610	2.590	2.832
April	1.572	1.464	1.532	1.713	1.642	1.604	0.141	0.178	0.072	2.920	2.864	2.715
May	1.638	1.575	1.746	1.823	1.713	1.834	0.186	0.138	0.088	3.130	2.824	3.146
June	1.725	1.214	1.260	2.130	2.140	1.673	0.405	0.926	0.413	3.210	3.360	3.340
July	1.523	1.428	1.836	1.813	1.924	2.240	0.290	0.496	0.404	3.070	3.035	2.351
August	1.617	1.666	1.448	1.816	1.917	2.106	0.199	0.251	0.658	2.561	3.139	3.328
September	1.219	1.288	1.331	1.501	1.602	1.462	0.282	0.314	0.131	2.819	2.703	2.784
October	1.391	1.372	1.482	1.581	1.703	1.572	0.190	0.331	0.090	3.151	0.915	3.795
November	1.732	1.280	1.732	1.831	1.953	1.842	0.099	0.673	0.011	3.261	2.064	1.735
December	1.142	1.343	1.242	1.231	1.354	1.286	0.089	0.011	0.044	1.437	2.465	2.473

CP-1: Chharat Pond 1; CP-2: Chharat Pond 2; MP: Medical Pond

Table 19
Statistical Briefs of Various Water Quality Parameters in CP-1, CP-2 and MP Wetlands.

Parameters	Parameters	Wetland	Coefficient of Correlation 'r'	Significance at ($p < 0.05$)
Air Temperature	Water Temperature	CP-1	0.987	✓
		CP-2	0.957	✓
		MP	0.843	✓
	Zooplankton	CP-1	-0.387	–
		CP-2	-0.654	✓
		MP	0.596	✓
Water Temperature	Dissolved Oxygen	CP-1	0.453	–
		CP-2	0.601	✓
		MP	-0.656	✓
	Zooplankton	CP-1	-0.304	–
		CP-2	-0.660	✓
		MP	0.788	✓
pH	Phytoplankton	CP-1	-0.296	–
		CP-2	0.273	–
		MP	-0.539	✓
	Zooplankton	CP-1	-0.679	✓
		CP-2	-0.645	✓
		MP	0.284	–
	Total Alkalinity	CP-1	0.572	✓
		CP-2	0.525	✓
		MP	0.245	–
Dissolved Oxygen	Zooplankton	CP-1	-0.319	–
		CP-2	-0.530	✓
		MP	-0.436	–
	Total Suspended Solids	CP-1	0.556	✓
		CP-2	0.534	✓
		MP	-0.232	–
	Total Solids	CP-1	0.640	✓
		CP-2	0.602	✓
		MP	-0.162	–
	Air Temperature	CP-1	0.662	✓
		CP-2	0.622	✓
		MP	-0.577	✓
Turbidity	Zooplankton	CP-1	0.735	✓
		CP-2	0.561	✓
		MP	0.618	✓
	Phytoplankton	CP-1	0.021	–
		CP-2	0.179	–
		MP	-0.774	✓

Chharat Pond-1 (CP-1), Chharat Pond-2 (CP-2), Medical Pond (MP)

Table 19 (contd.)

Statistical Briefs of Various Water Quality Parameters in CP-1, CP-2 and MP Wetlands.

Parameters	Parameters	Stations	Coefficient of Correlation (r value)	Significant at ($p < 0.05$)
	Total Suspended Solids	CP-1	-0.377	–
		CP-2	-0.771	✓
		MP	-0.133	–
	Total Solids	CP-1	-0.787	✓
		CP-2	-0.910	✓
		MP	-0.540	✓
Total Solids	Zooplankton	CP-1	-0.516	✓
		CP-2	-0.513	✓
		MP	-0.045	–
Total Dissolved Solids	Zooplankton	CP-1	-0.619	✓
		CP-2	-0.214	–
		MP	-0.082	–
Total Suspended Solids	Zooplankton	CP-1	-0.061	–
		CP-2	-0.602	✓
		MP	0.129	–
Transparency	Phytoplankton	CP-1	-0.111	–
		CP-2	0.239	–
		MP	-0.350	–
	Zooplankton	CP-1	0.461	–
		CP-2	0.334	–
		MP	0.794	✓
	Total Suspended Solids	CP-1	-0.519	✓
		CP-2	-0.614	✓
		MP	0.153	–
	Total Dissolved Solids	CP-1	-0.566	✓
		CP-2	-0.491	✓
		MP	-0.355	–
	Total Solids	CP-1	-0.769	✓
		CP-2	-0.815	✓
		MP	-0.310	–
	Turbidity	CP-1	0.891	✓
		CP-2	0.809	✓
		MP	0.692	✓
	Dissolved Oxygen	CP-1	-0.683	✓
		CP-2	-0.481	–
		MP	-0.312	–
Calcium	Phytoplankton	CP-1	-0.136	–
		CP-2	0.515	✓
		MP	0.315	–

Chharat Pond-1 (CP-1), Chharat Pond-2 (CP-2), Medical Pond (MP)

Table 19 (contd.)

Statistical Briefs of Various Water Quality Parameters in CP-1, CP-2 and MP Wetlands.

Parameters	Parameters	Stations	Coefficient of Correlation (r value)	Significant at ($p < 0.05$)
	Total Dissolved Solids	CP-1	0.084	–
		CP-2	-0.597	✓
		MP	0.283	–
Magnesium	Phytoplankton	CP-1	-0.052	–
		CP-2	0.567	✓
		MP	0.139	–
	Zooplankton	CP-1	-0.279	–
		CP-2	-0.156	–
		MP	-0.349	–
Chloride	Zooplankton	CP-1	-0.646	✓
		CP-2	-0.320	–
		MP	0.505	✓
	Phytoplankton	CP-1	-0.711	✓
		CP-2	-0.283	–
		MP	0.185	–
	Silica	CP-1	0.297	–
		CP-2	-0.190	–
		MP	0.556	✓
Phosphate-Phosphorus	Zooplankton	CP-1	-0.550	✓
		CP-2	-0.550	✓
		MP	-0.423	–
	Phytoplankton	CP-1	0.317	–
		CP-2	0.351	–
		MP	0.462	–
	Nitrate-Nitrogen	CP-1	-0.509	✓
		CP-2	-0.503	✓
		MP	-0.393	–
	Total Suspended Solids	CP-1	0.007	–
		CP-2	0.530	✓
		MP	0.011	–
Sulphate-Sulphur	Total Dissolved Solids	CP-1	0.628	✓
		CP-2	0.114	–
		MP	0.458	–
Silica	Phytoplankton	CP-1	-0.051	–
		CP-2	-0.516	✓
		MP	0.278	–
Ammonia-Nitrogen	Phytoplankton	CP-1	-0.317	–
		CP-2	-0.439	–
		MP	0.687	✓

Chharat Pond-1 (CP-1), Chharat Pond-2 (CP-2), Medical Pond (MP)

Table 19 (contd.)

Statistical Briefs of Various Water Quality Parameters in CP-1, CP-2 and MP Wetlands.

Parameters	**Parameters**	**Stations**	**Coefficient of Correlation (r value)**	**Significant at ($p < 0.05$)**
Nitrite-Nitrogen	Phytoplankton	CP-1	-0.099	–
		CP-2	-0.195	–
		MP	0.445	–
Nitrate-Nitrogen	Phytoplankton	CP-1	-0.241	–
		CP-2	-0.252	–
		MP	-0.349	–
Zooplankton	Phytoplankton	CP-1	0.552	✓
		CP-2	-0.316	–
		MP	-0.266	–
	Sulphate-Sulphur	CP-1	-0.639	✓
		CP-2	-0.651	✓
		MP	0.010	–
Diatoms	Silica	CP-1	-0.275	–
		CP-2	-0.364	–
		MP	0.170	–
Rotifers	Water Temperature	CP-1	0.241	–
		CP-2	-0.524	✓
		MP	0.736	✓
	PH	CP-1	-0.687	✓
		CP-2	-0.736	✓
		MP	0.256	–
	Turbidity	CP-1	0.090	–
		CP-2	0.406	–
		MP	0.776	✓
	Transparency	CP-1	-0.231	–
		CP-2	0.245	–
		MP	0.854	✓
Gross Primary Productivity	Chlorophyll 'a'	CP-1	0.887	✓
		CP-2	0.704	✓
		MP	0.536	✓
	Water Temperature	CP-1	0.663	✓
		CP-2	0.693	✓
		MP	0.703	✓
	Phytoplankton	CP-1	0.005	–
		CP-2	-0.570	✓
		MP	-0.138	–
Net Primary Productivity	Phytoplankton	CP-1	0.044	–
		CP-2	-0.445	–
		MP	-0.162	–

Chharat Pond-1 (CP-1), Chharat Pond-2 (CP-2), Medical Pond (MP)

Table 19 (contd.)

Statistical Briefs of Various Water Quality Parameters in CP-1, CP-2 and MP Wetlands.

Parameters	**Parameters**	**Wetland**	**Coefficient of Correlation 'r'**	**Significance at ($p < 0.05$)**
	Chlorophyll 'a'	CP-1	0.865	✓
		CP-2	0.742	✓
		MP	0.497	✓
	Air Temperature	CP-1	0.611	✓
		CP-2	0.633	✓
		MP	0.526	✓
	Water Temperature	CP-1	0.556	✓
		CP-2	0.602	✓
		MP	0.415	–
Chlorophyll 'a'	Phytoplankton	CP-1	0.133	–
		CP-2	-0.333	–
		MP	0.031	–
Total Dissolved Solids	Magnesium	CP-1	0.261	–
		CP-2	-0.346	–
		MP	-0.249	–
	Chloride	CP-1	0.213	–
		CP-2	0.054	–
		MP	0.141	–

Chharat Pond-1 (CP-1), Chharat Pond-2 (CP-2), Medical Pond (MP)

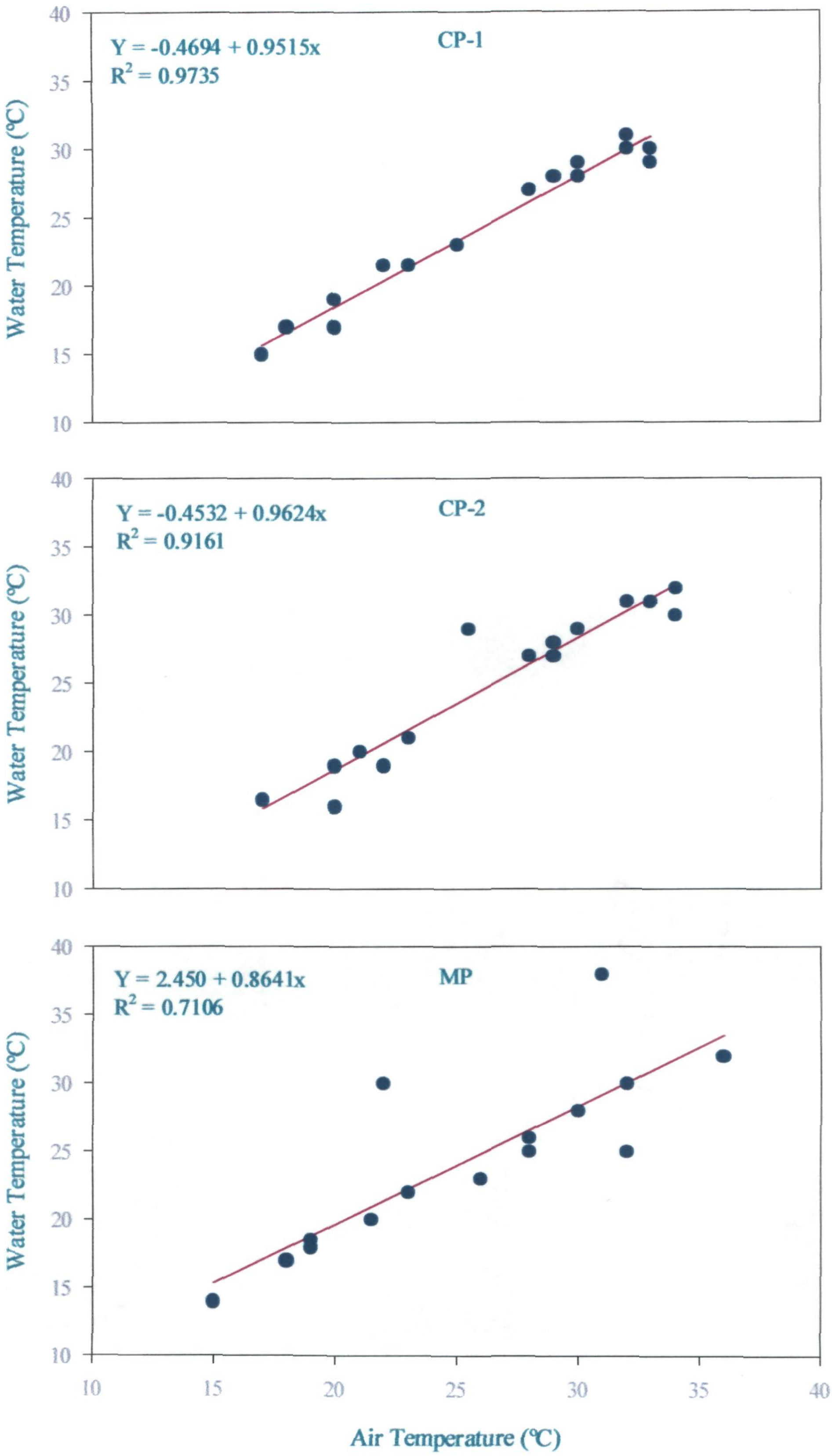

Fig. 12. Regression lines showing correlation between Air Temperature and Water Temperature in the wetlands.

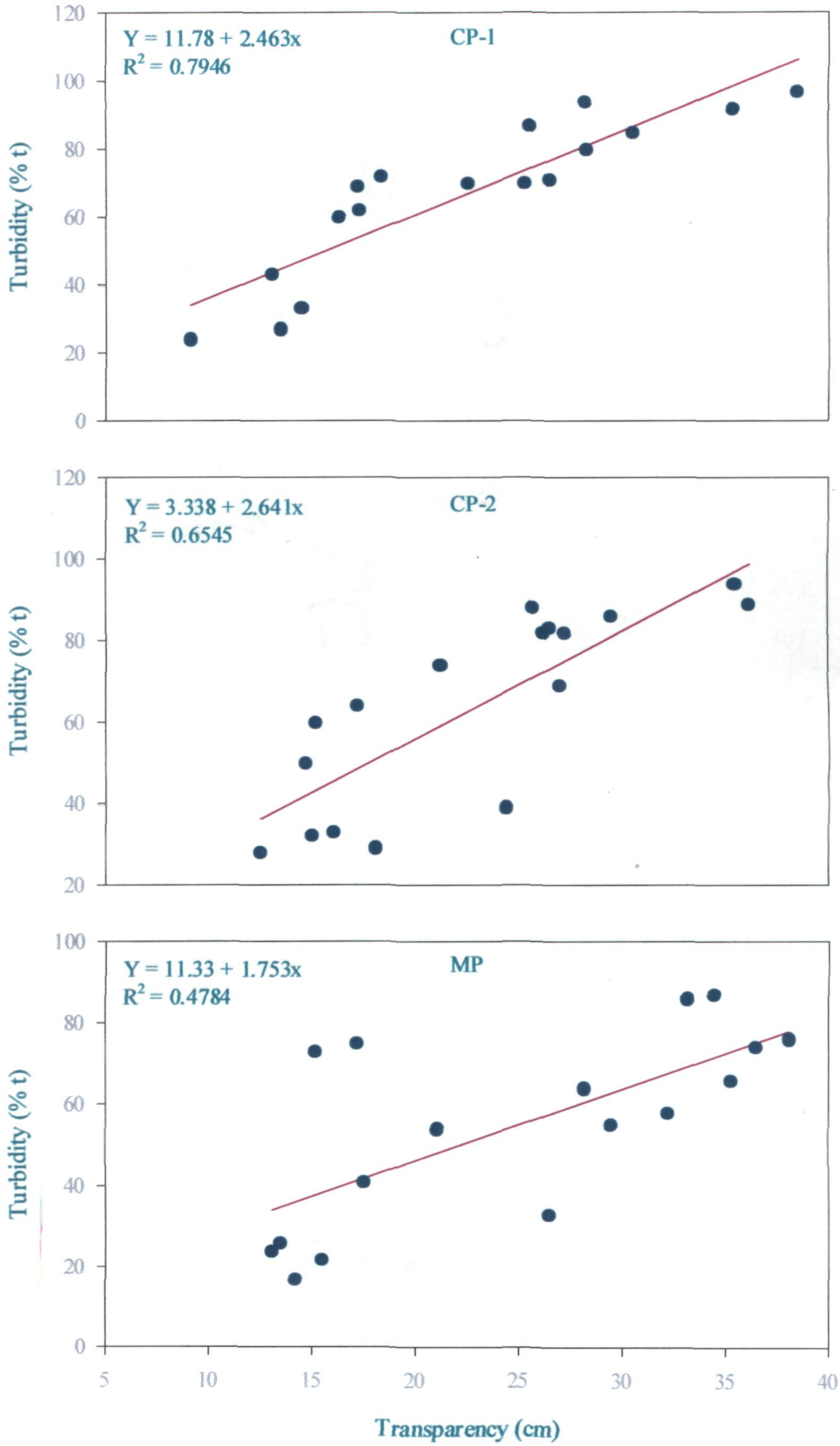

Fig. 13. Regression lines showing correlation between Transparency and Turbidity in the wetlands.

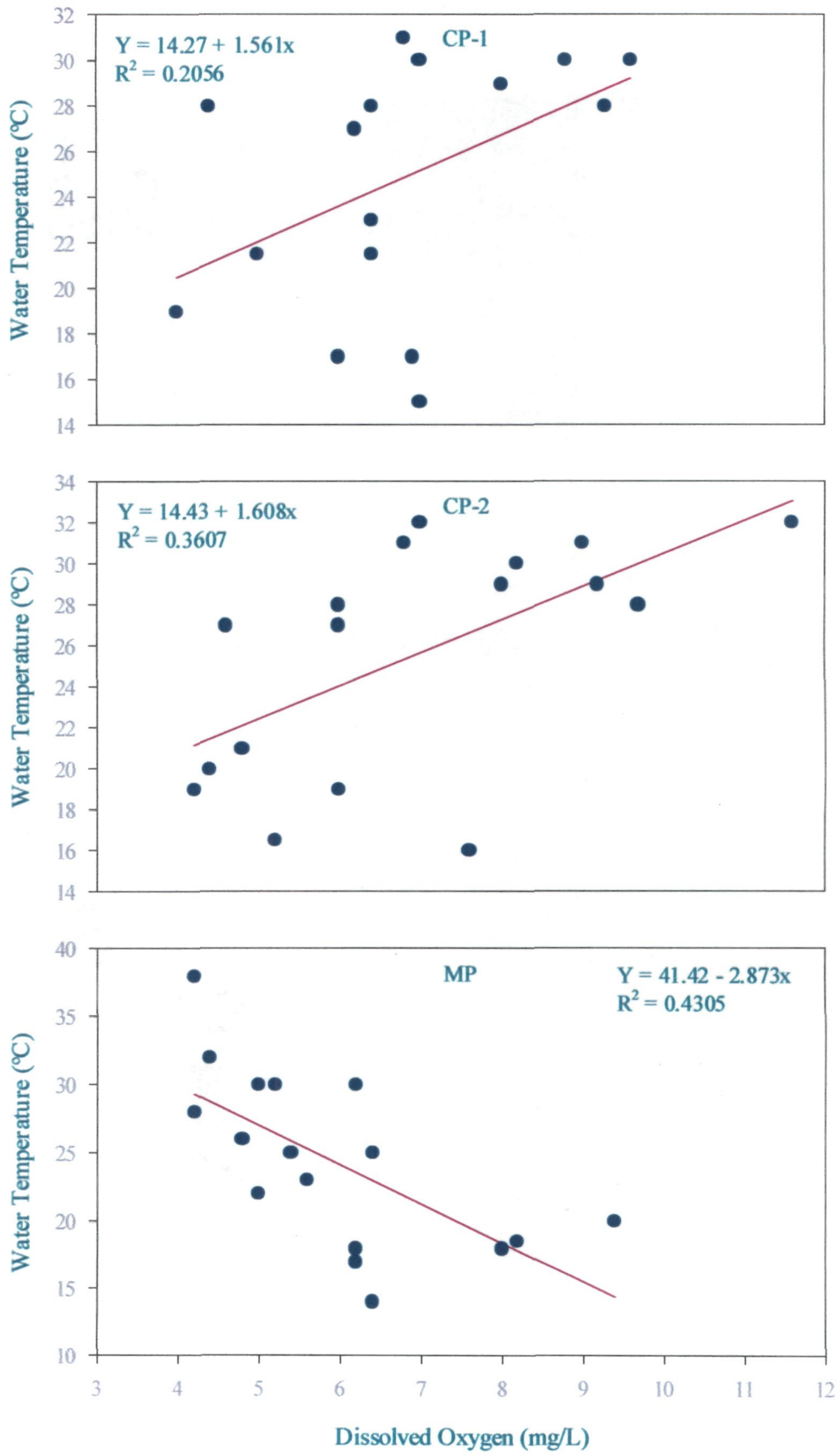

Fig. 14. Regression lines showing correlation between Dissolved Oxygen and Water Temperature in the wetlands.

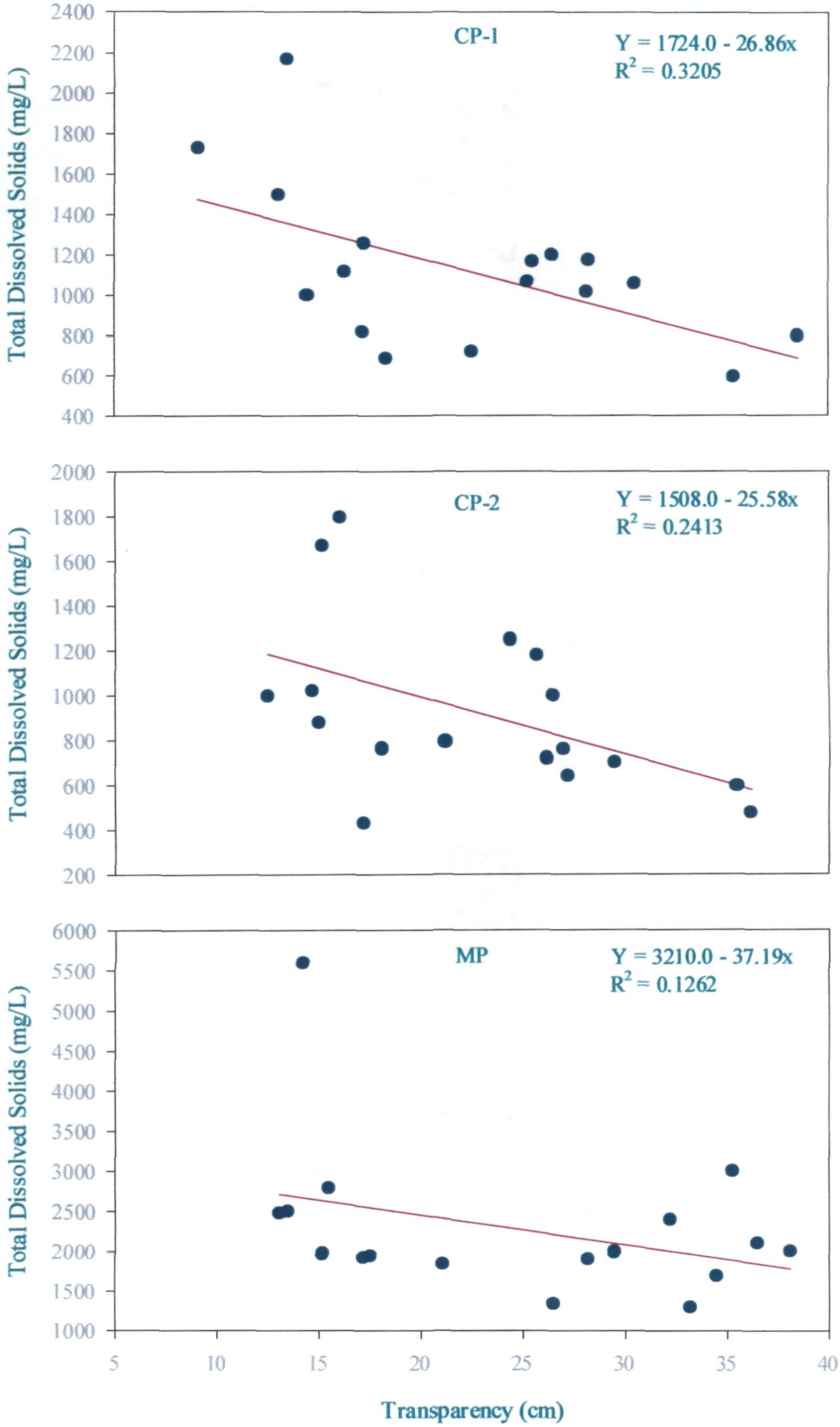

Fig. 15. Regression lines showing correlation between Transparency and Total Dissolved Solids in the wetlands.

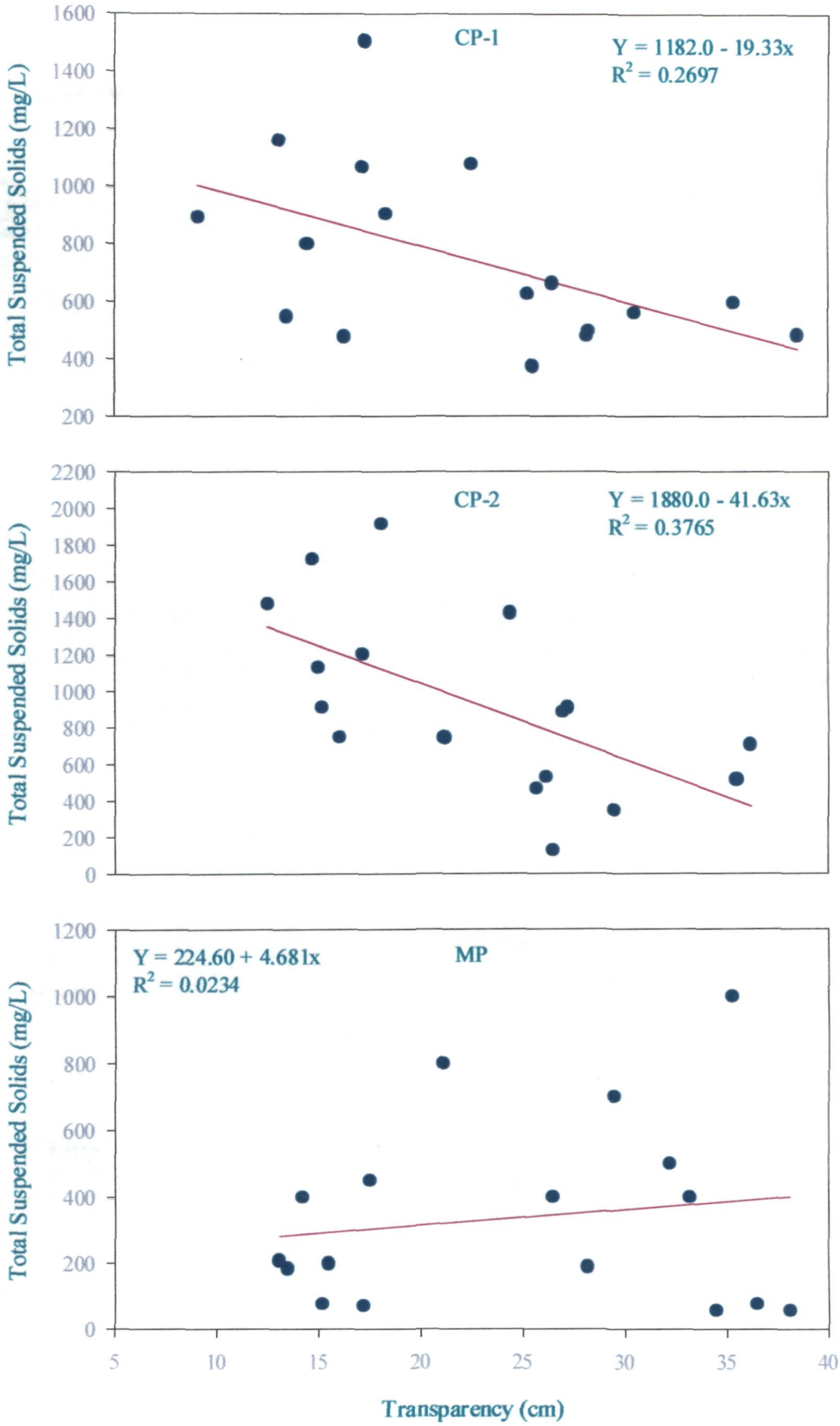

Fig. 16. Regression lines showing correlation between Transparency and Total Suspended Solids in the wetlands.

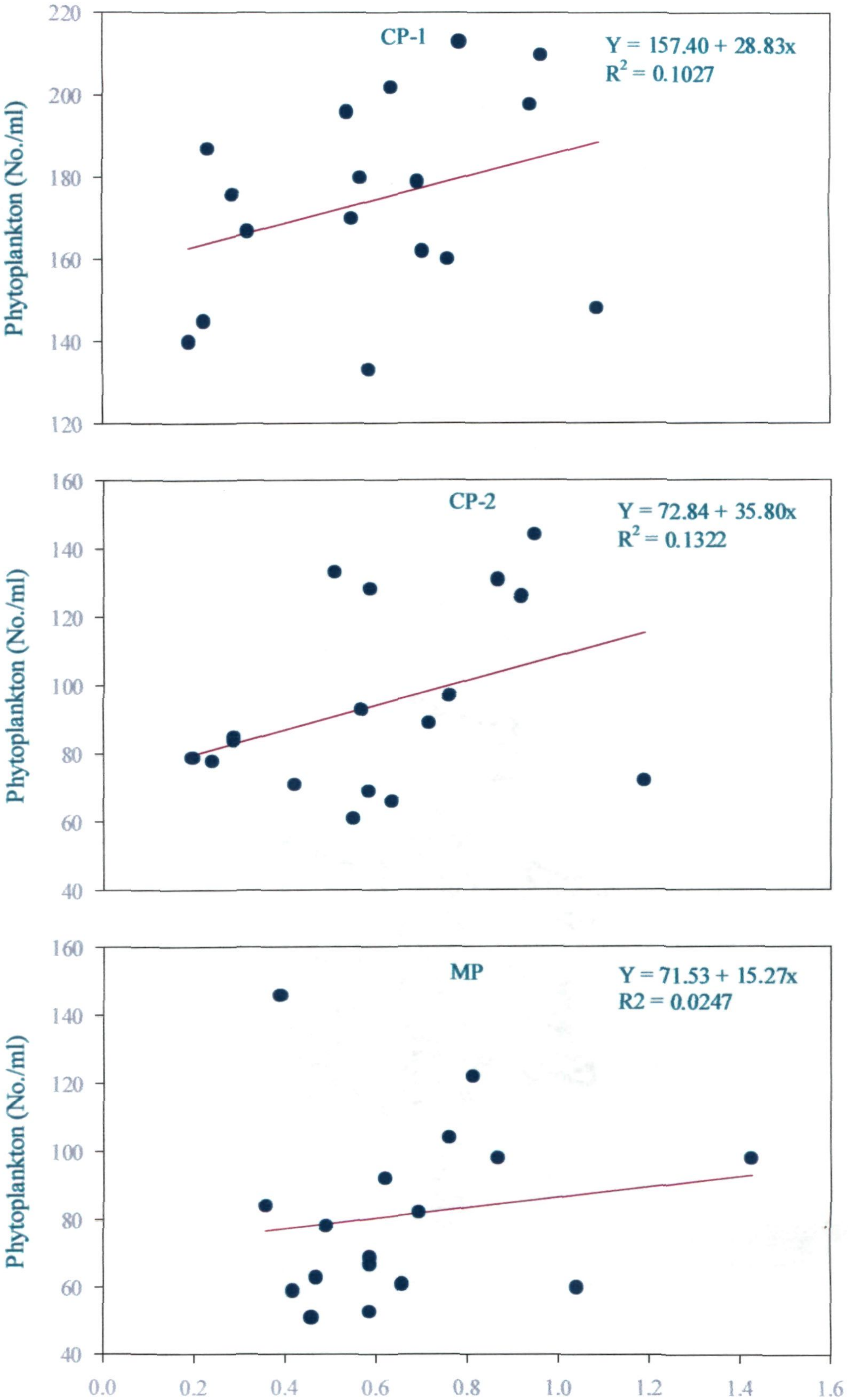

Fig. 17. Regression lines showing correlation between Phosphate-Phosphorus and Phytoplankton in the wetlands.

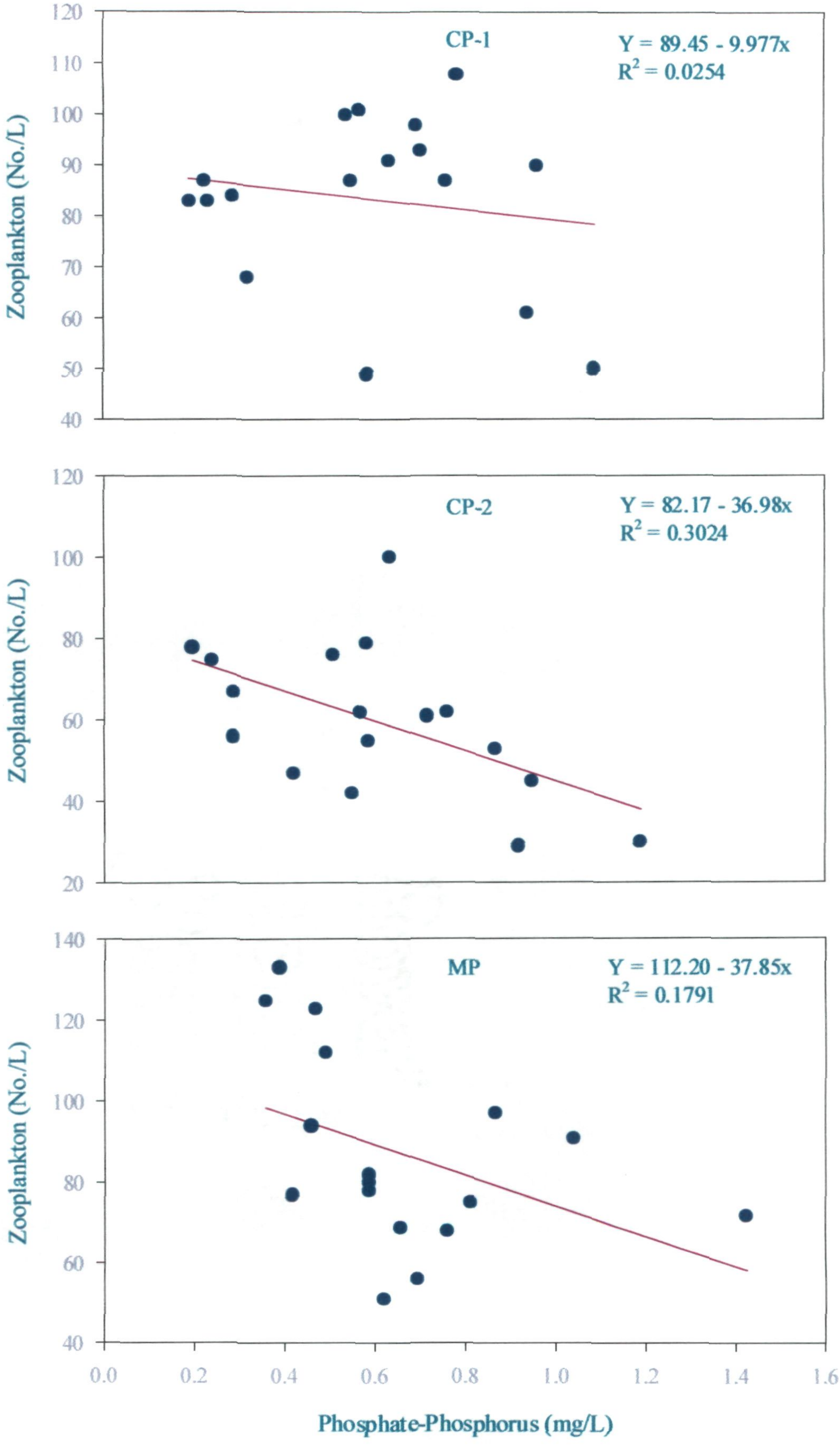

Fig. 18. Regression lines showing correlation between Phosphate-Phosphorus and Zooplankton in the wetlands.

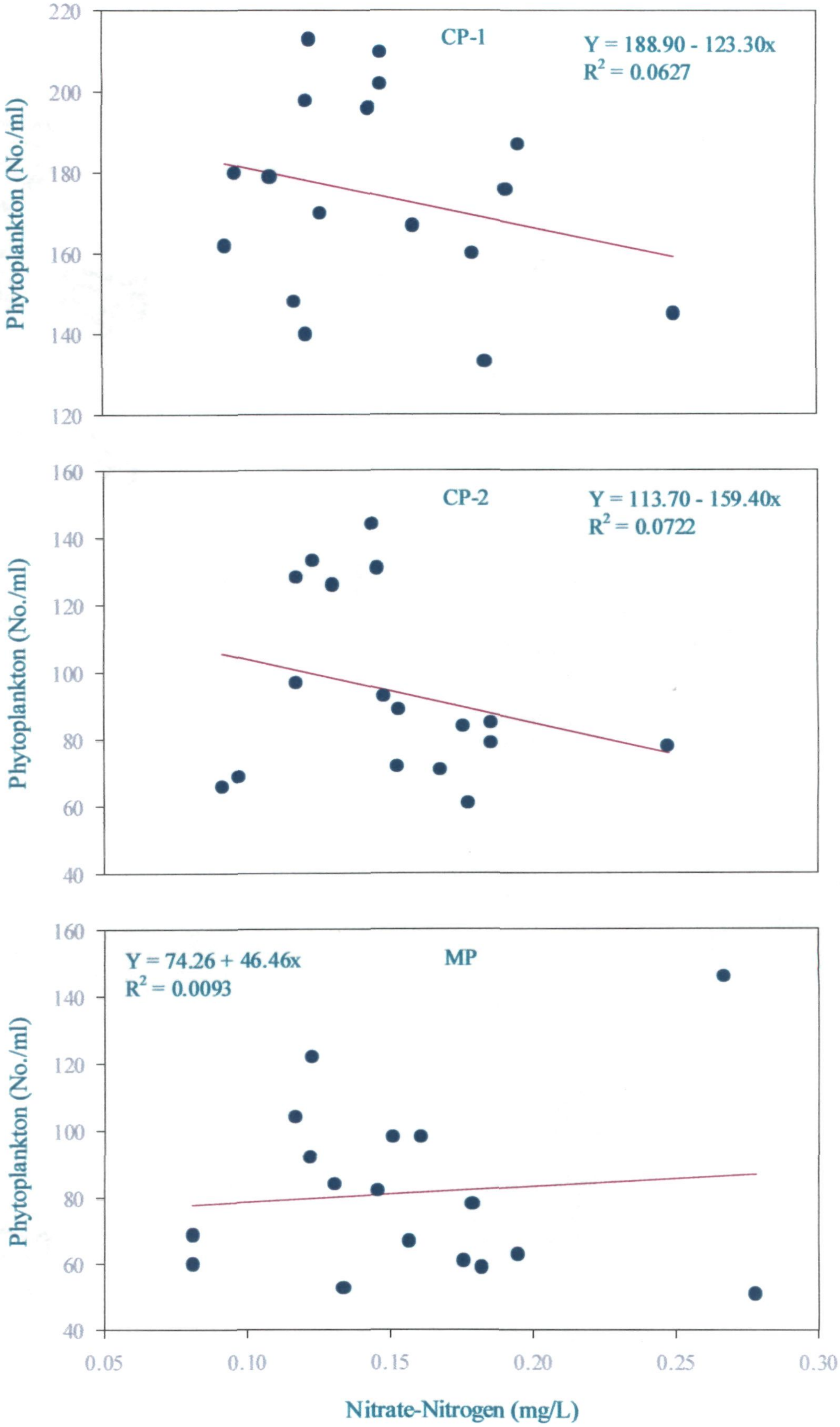

Fig. 19. Regression lines showing correlation between Nitrate-Nitrogen and Phytoplankton in the wetlands.

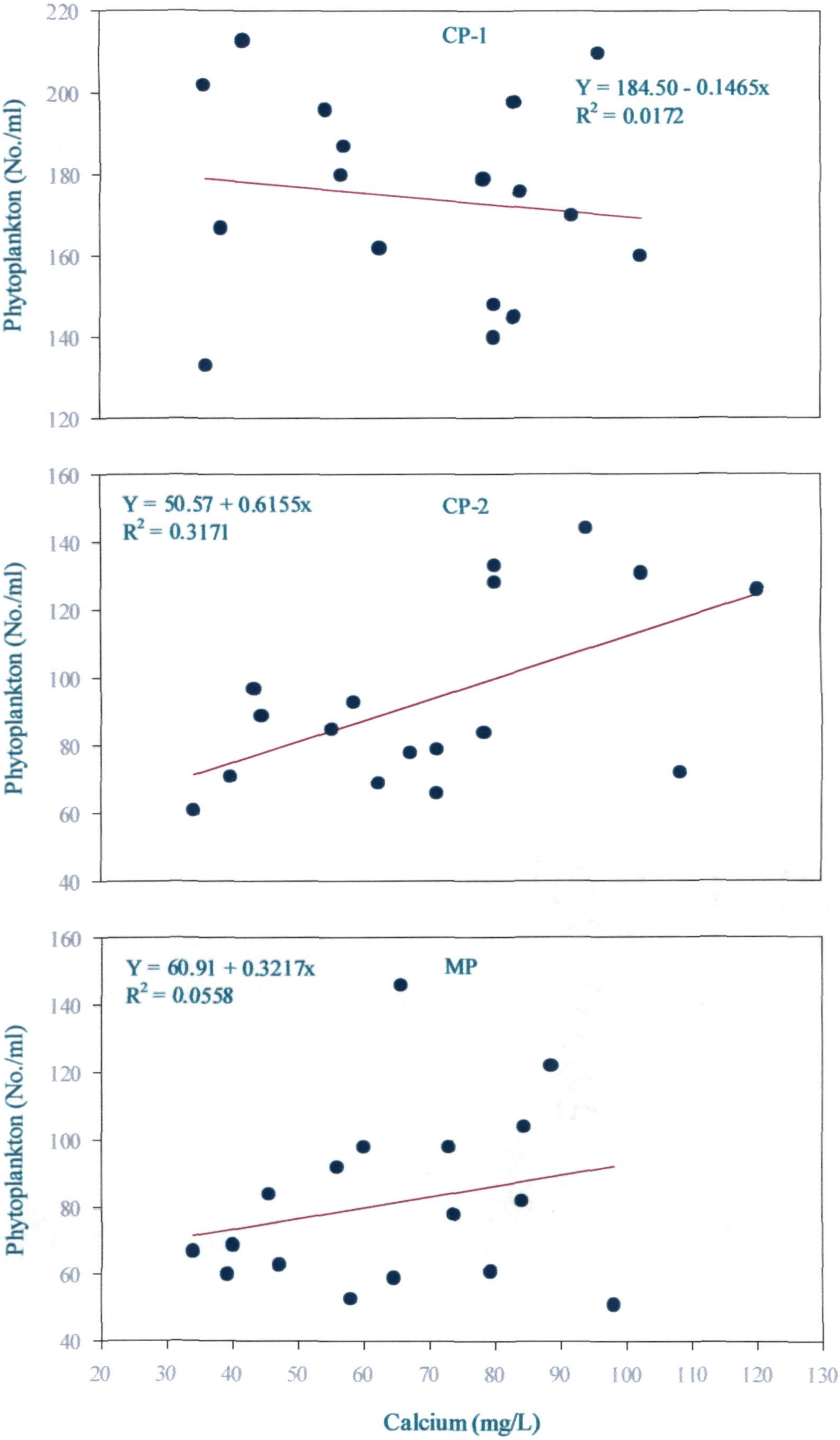

Fig. 20. Regression lines showing correlation between Calcium and Phytoplankton in the wetlands.

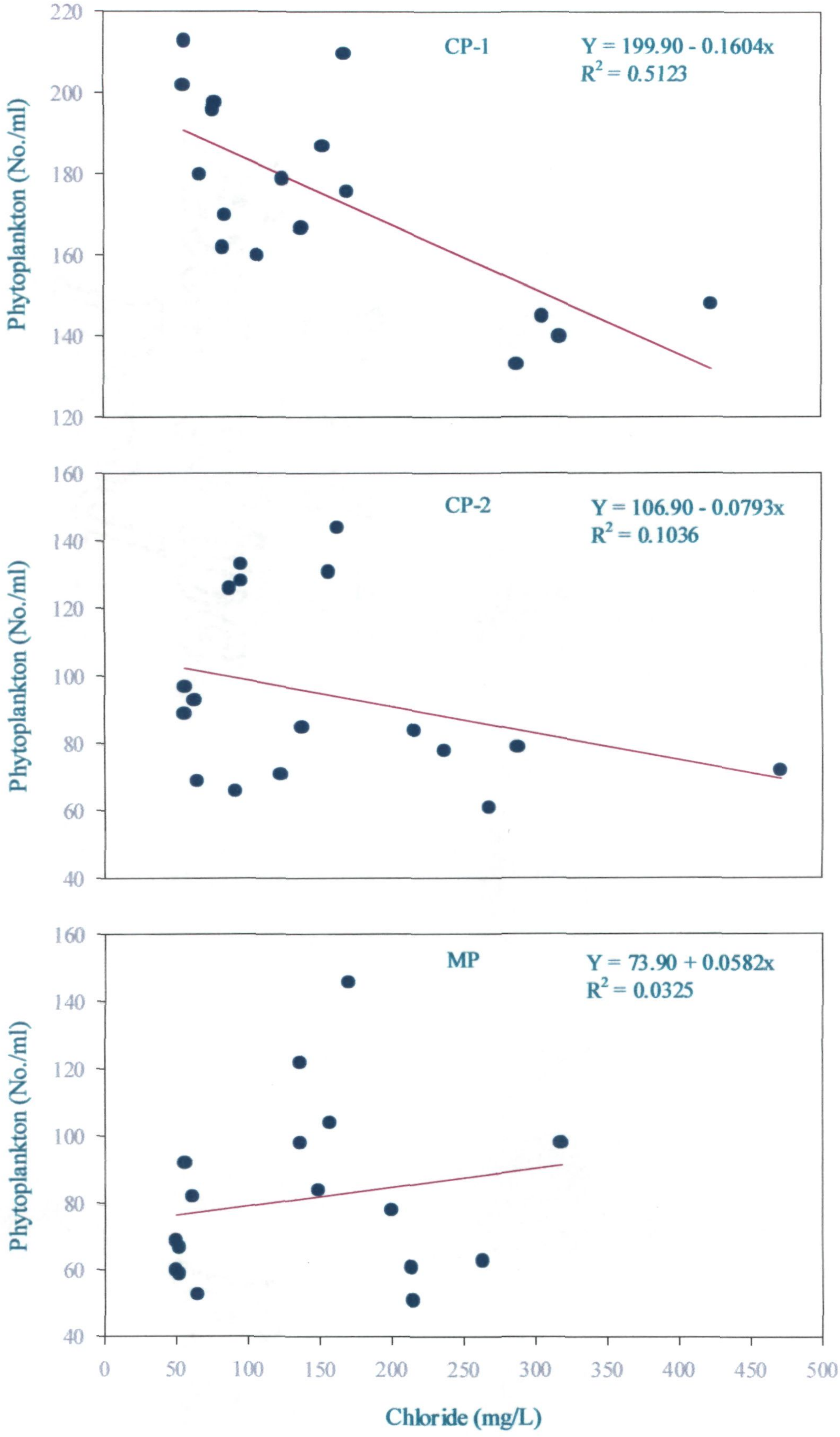

Fig. 21. Regression lines showing correlation between Chloride and Phytoplankton in the wetlands.

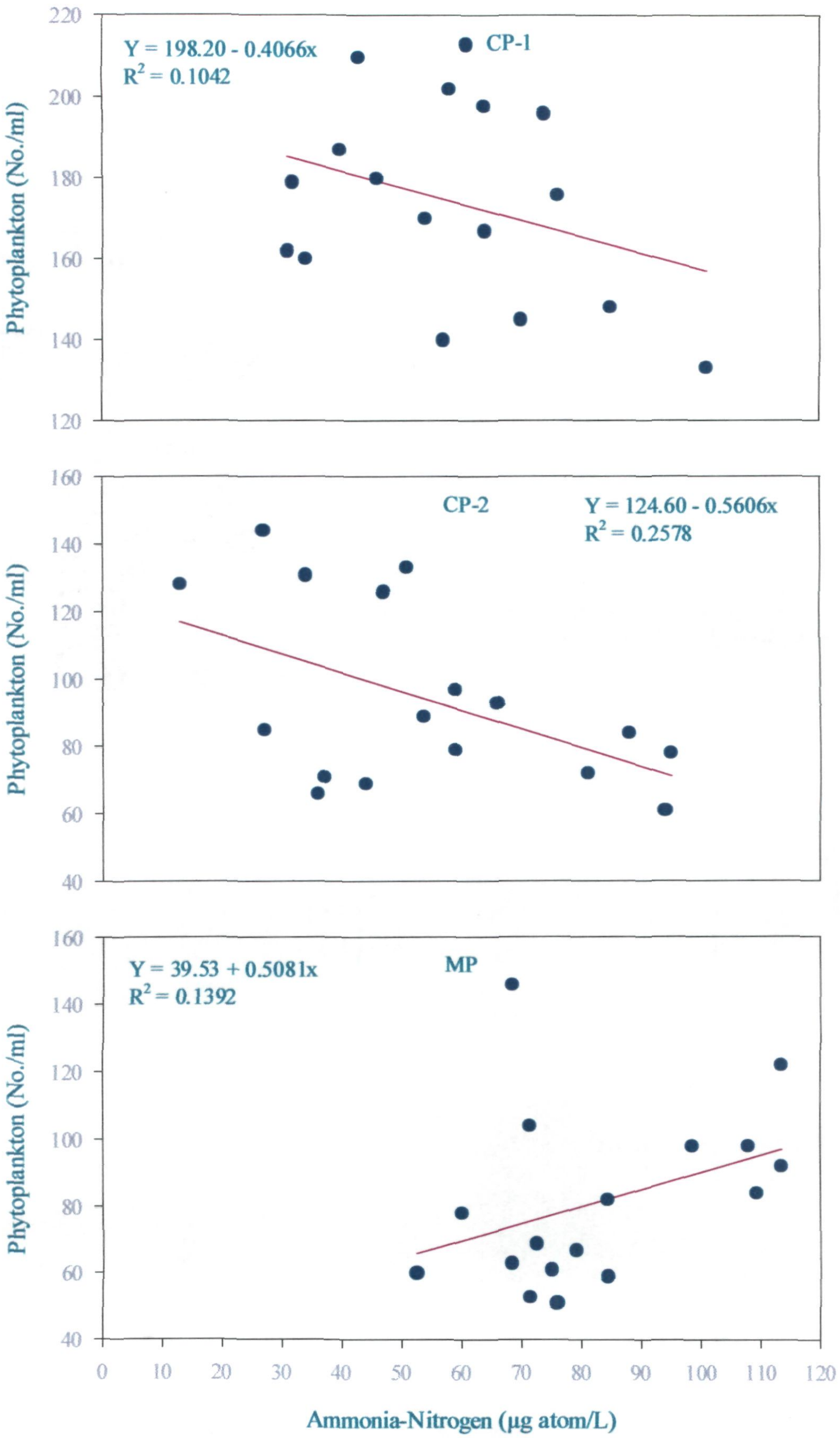

Fig. 22. Regression lines showing correlation between Ammonia-Nitrogen and Phytoplankton in the wetlands.

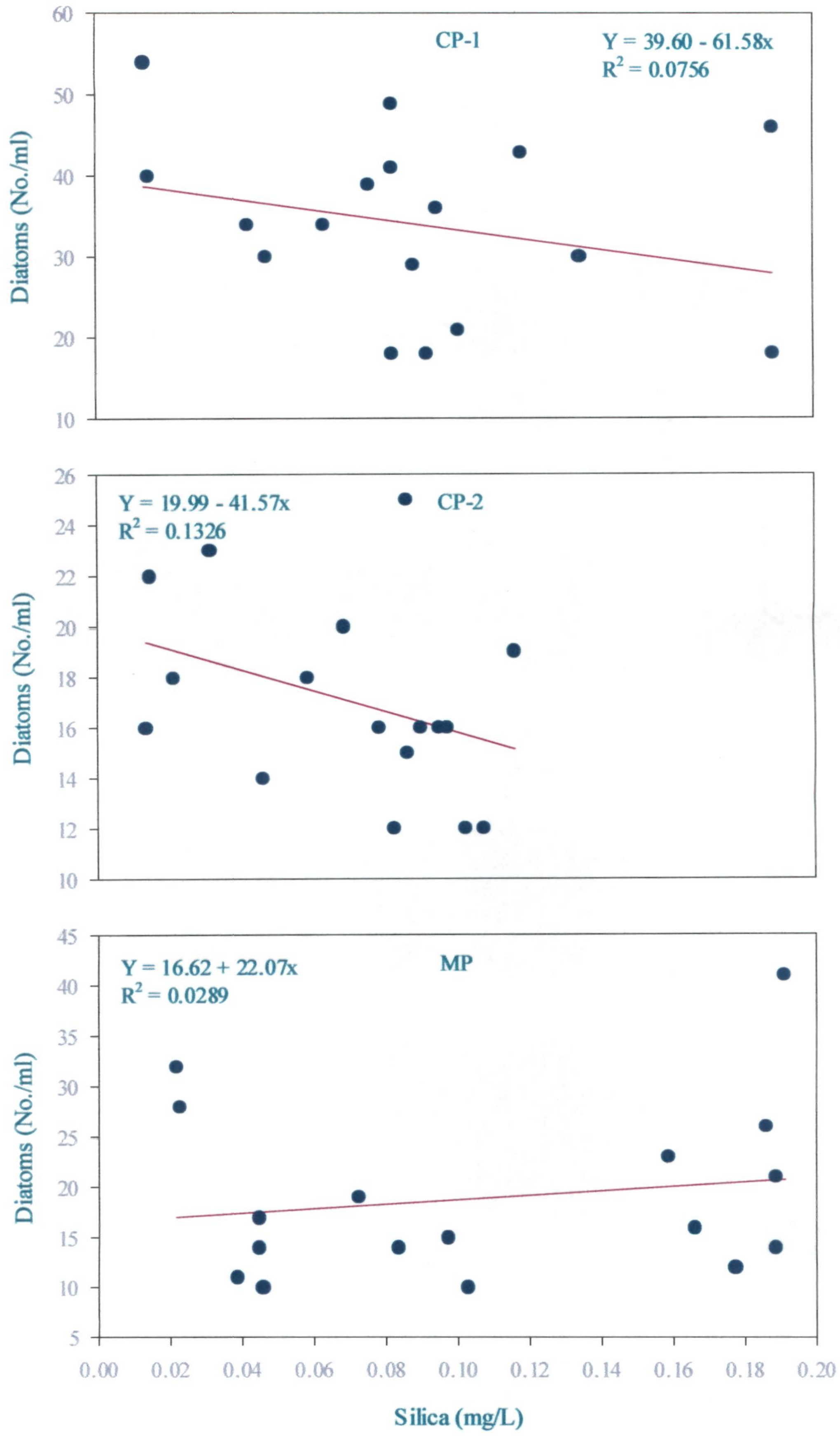

Fig. 23. Regression lines showing correlation between Silica and Diatoms in the wetlands.

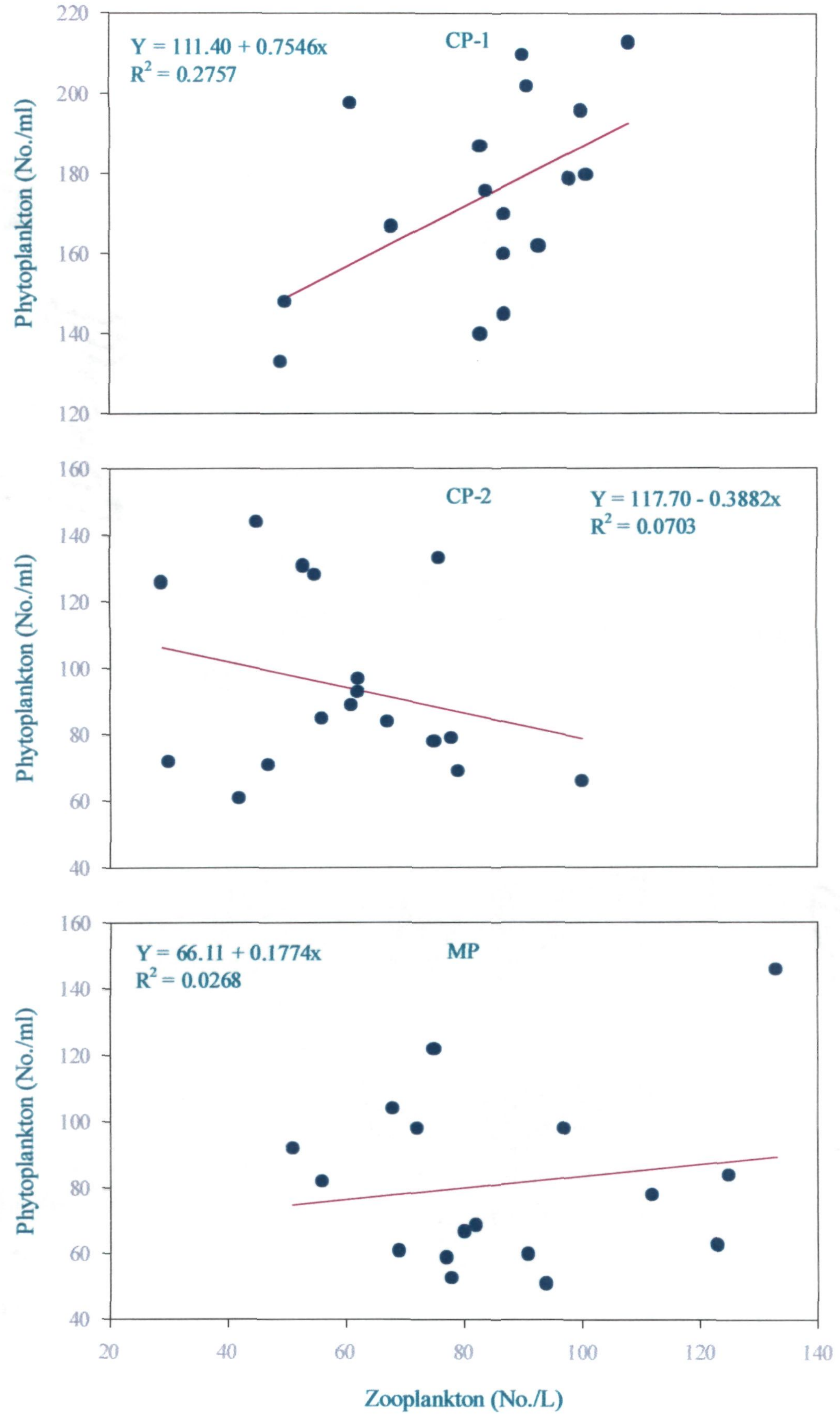

Fig. 24. Regression lines showing correlation between Zooplankton and Phytoplankton in the wetlands.

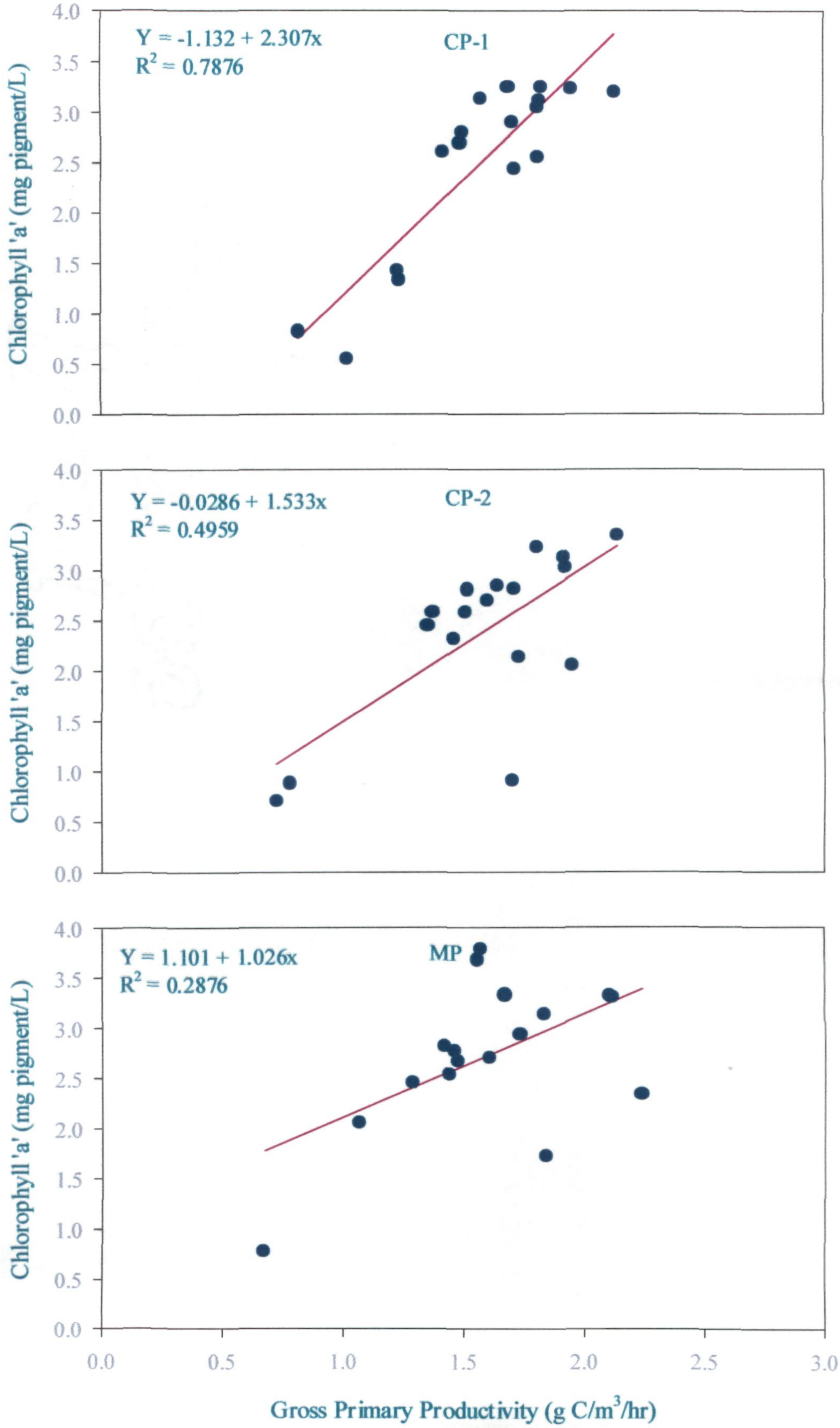

Fig. 25. Regression lines showing correlation between Gross Primary Productivity and Chlorophyll 'a' in the wetlands.

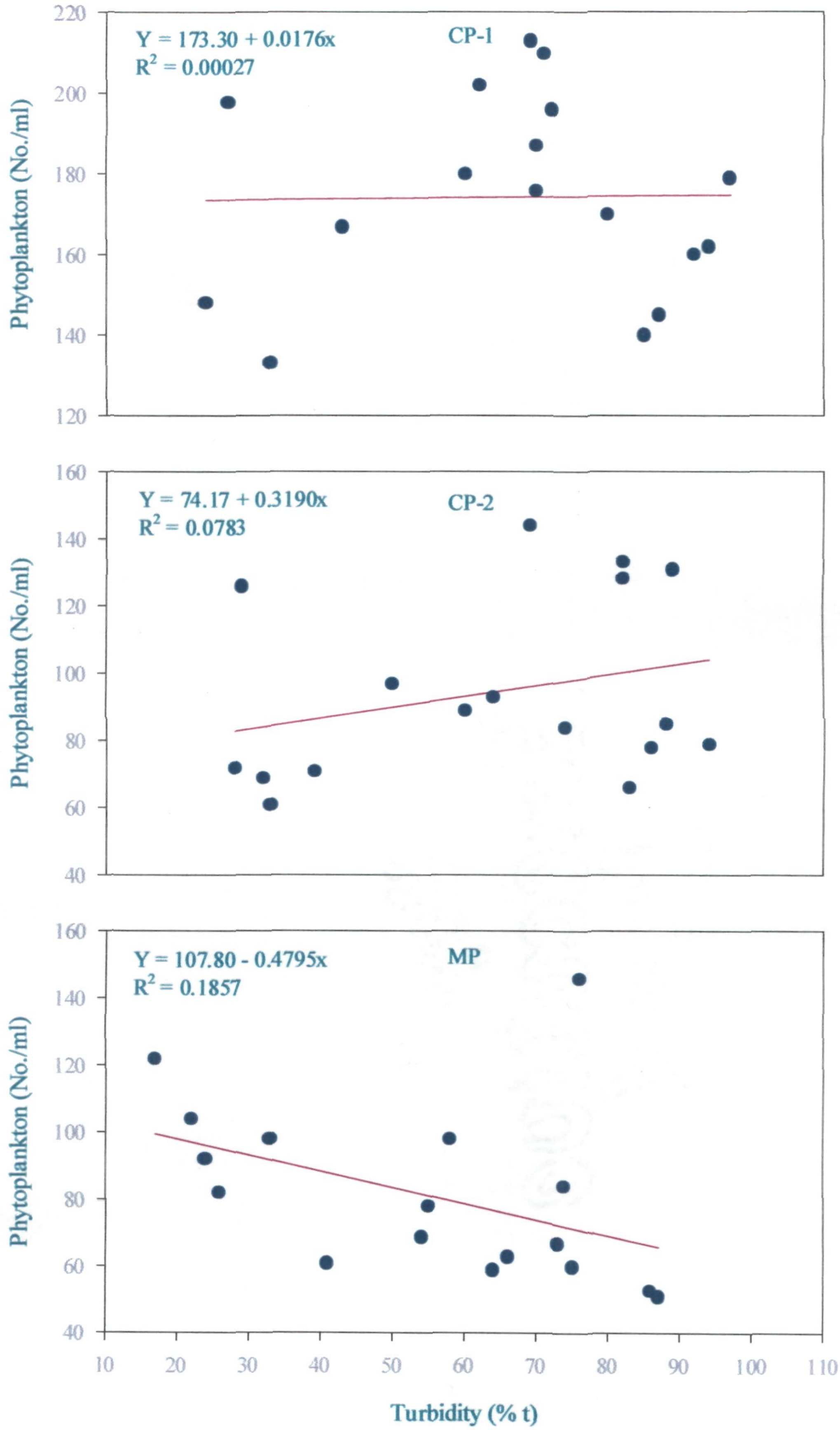

Fig. 26. Regression lines showing correlation between Turbidity and Phytoplankton in the wetlands.

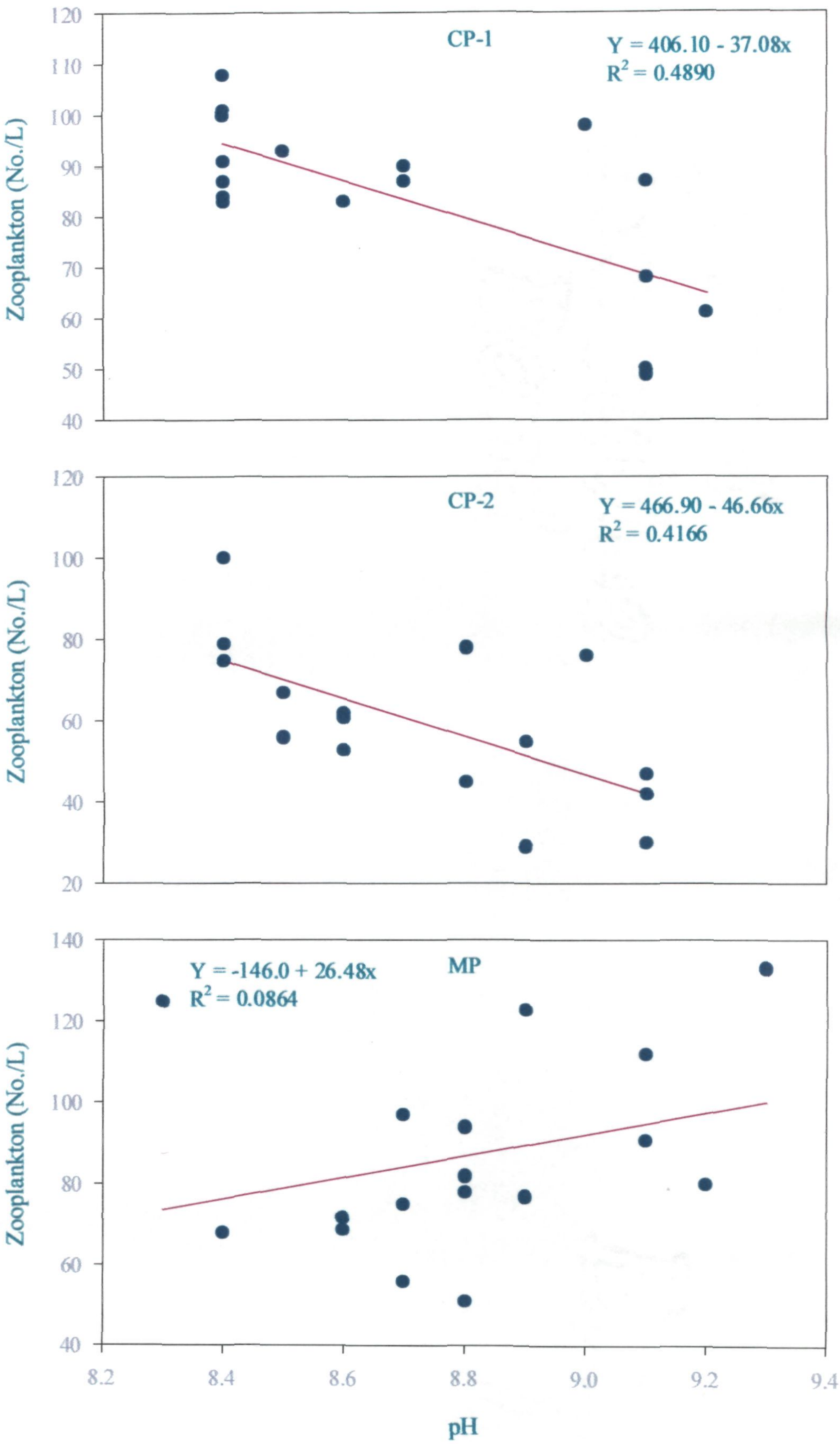

Fig. 27. Regression lines showing correlation between pH and Zooplankton in the wetlands.

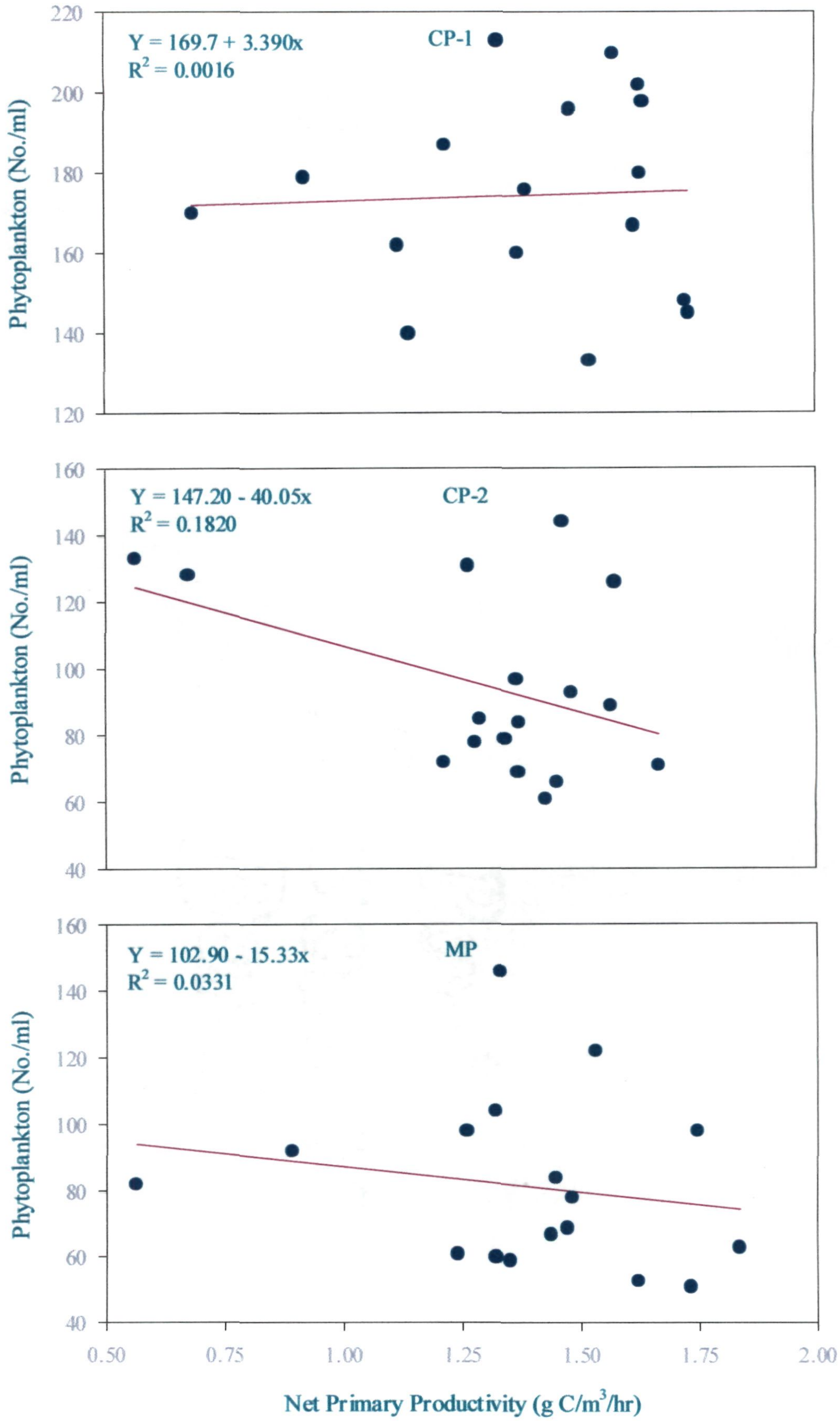

Fig. 28. Regression lines showing correlation between Net Primary Productivity and Phytoplankton in the wetlands.

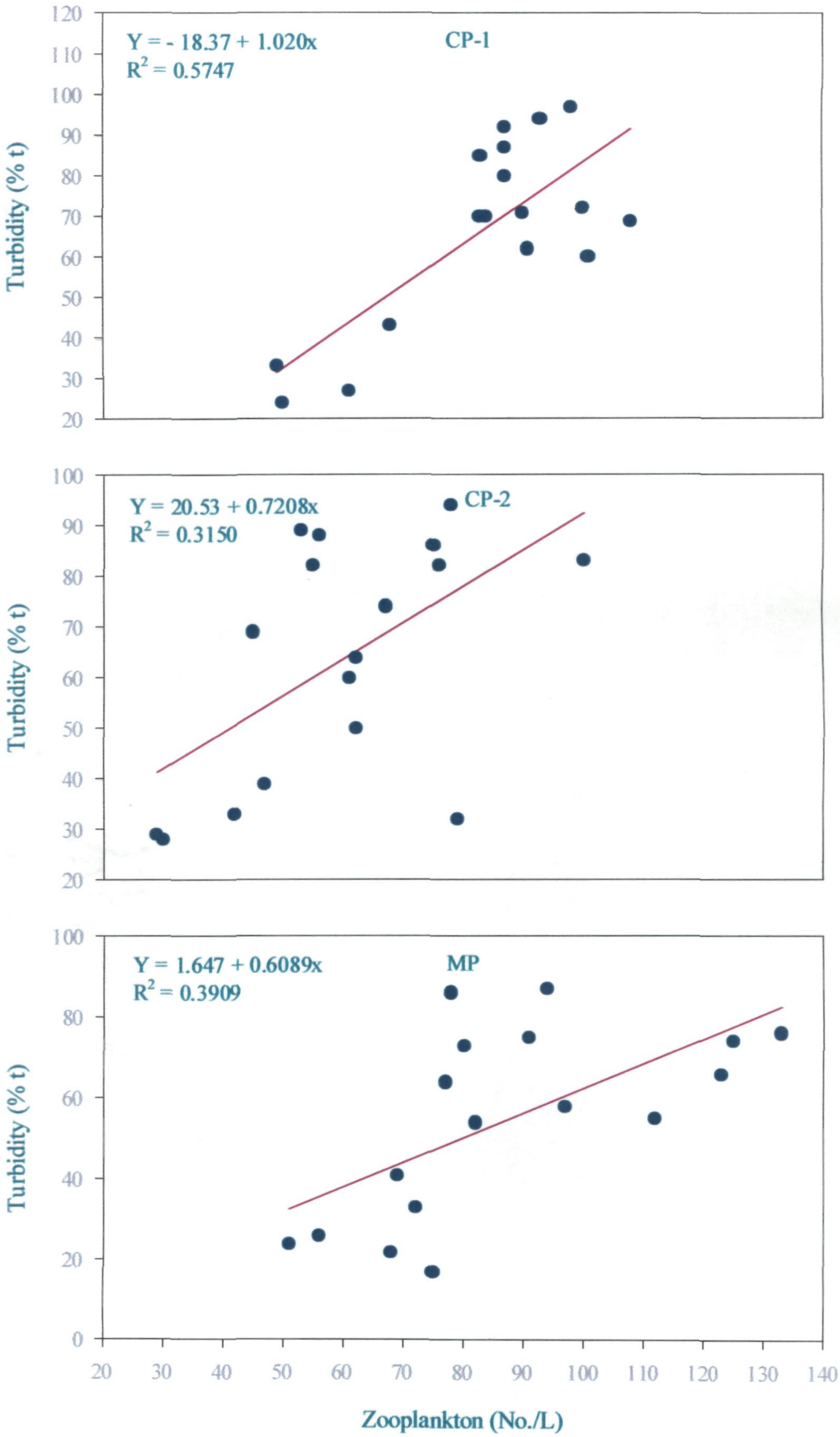

Fig. 29. Regression lines showing correlation between Zooplankton and Turbidity in the wetlands.

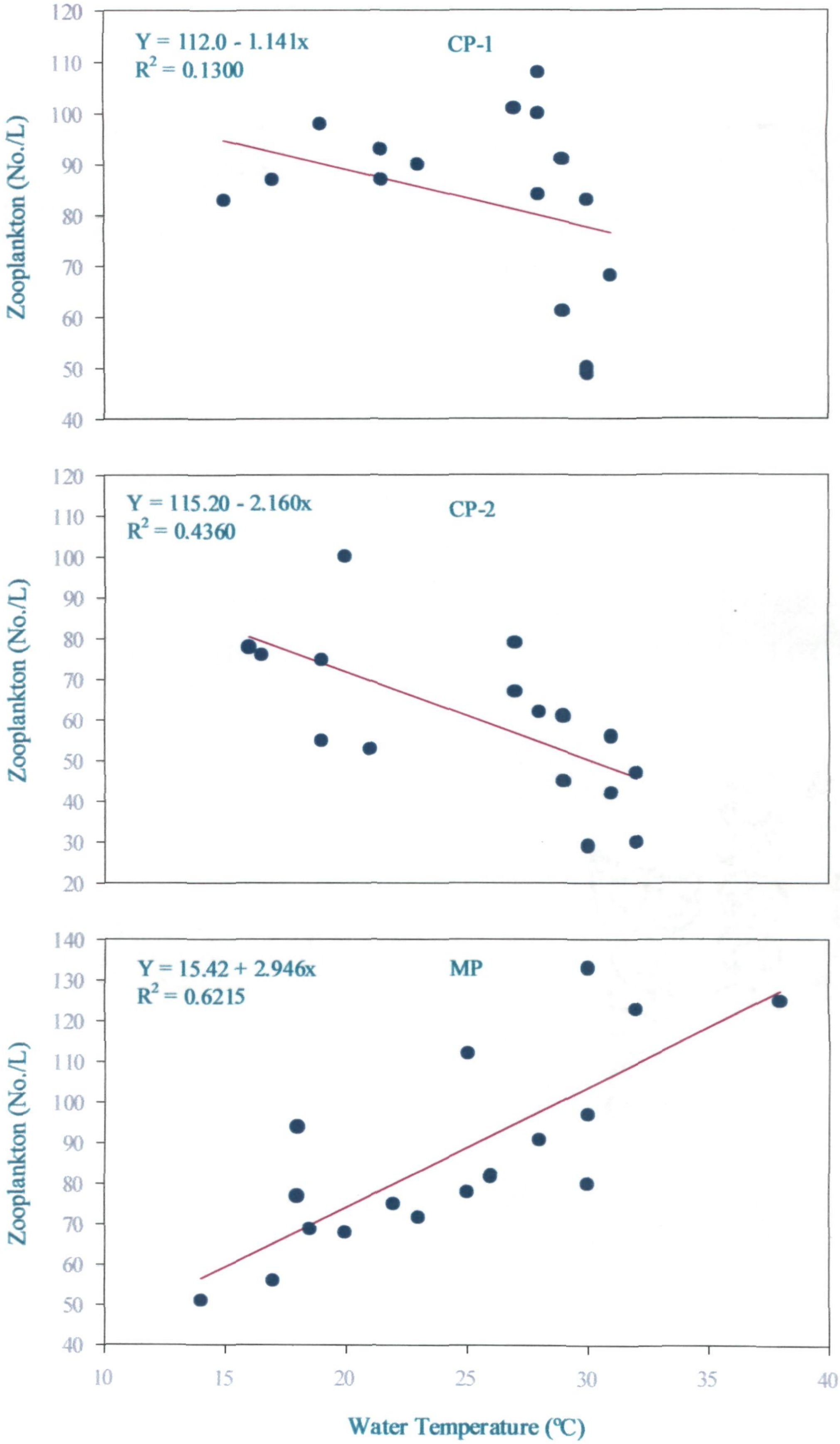

Fig. 30. Regression lines showing correlation between Water Temperature and Zooplankton in the wetlands.

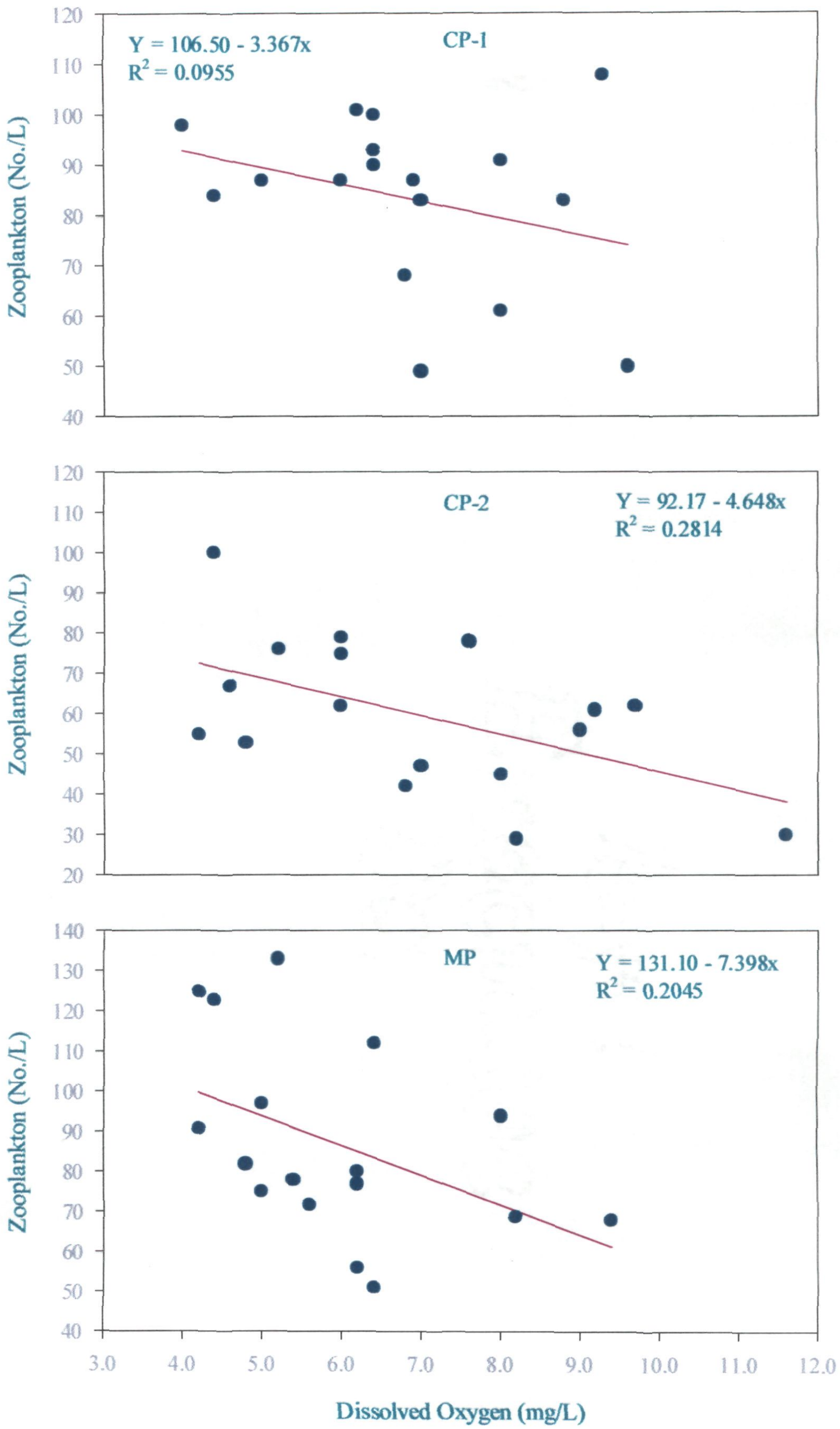

Fig. 31. Regression lines showing correlation between Dissolved Oxygen and Zooplankton in the wetlands.

Chapter VI

SUMMARY AND RECOMMENDATION

SUMMARY AND RECOMMENDATION

In the present investigations, three wetlands were selected to make the preliminary limnological study during August, 2000 to December, 2001. The main objective was to evaluate water quality of these untouched wetlands and study the environmental stress on these wetlands.

1. Most of the months showed great seasonal fluctuations in air and surface water temperatures. The pattern of seasonal fluctuations in air and water temperature broadly agrees with the solar radiation and the photoperiods of the seasons.
2. The values of transparency and turbidity showed wide seasonal fluctuations, mainly caused by silt, clay, micro-organisms, suspended organic and inorganic matters etc. Significant inverse relationship was obtained between Transparency and T.S.S. and T.D.S.
3. D.O. content in these wetlands varied from 4.0 to 11.6 mg/L showing wide seasonal fluctuations during different months of the study. These variations in D.O. content were found to be directly related with changes in phytoplankton density. Average values of D.O. were always found above 4.0mg/L indicating that the wetlands are very well aerated and can be utilised for aquaculture activities.
4. Alkalinity was found to be represented by carbonates and bicarbonates except in few months when bicarbonate alkalinity is replaced by hydroxide alkalinity.
5. pH values were always found 8.4 or more throughout the study. These wetlands can be placed under *alkaliphilous* and *alkalibiontic* during different months of the study.
6. CO_2 was never detected in these wetlands. Its absence in all the samples may be attributed to increased pH values as has been reported by many workers or it may also be due to its complete utilization during photosynthesis by green aquatic biota.
7. Hardness, which plays a key role in buffering capacity was found to vary between 124 to 392 mg/L during the periods of investigations. As per

classification given by various workers, these wetlands are categorised under *moderately hard* to *hard*.

8. T.D.S., which is regarded as one of the important indices of productivity of inland waters, were found to vary between 435 to 5600 mg/L during different months of the study. Wide seasonal and monthly fluctuations were noted in *calcium*, *magnesium*, *chloride* and *sulphate*. After following Ohle's (1938) classification, these wetlands fall under the category of *calcium rich* waters.
9. Chloride was found to be contributed mainly through sewage and surface run-off during different seasons. Increased concentrations of chloride indicate eutrophic nature of these wetlands. A significant positive correlation was obtained between chloride and phytoplankton at CP-1.
10. Higher concentrations of *sulphates*, as recorded during summer, were found to be related with fast blowing hot and dry winds causing increased evaporation in these wetlands. The permissible upper limit for sulphate ions in the water for human consumption is 50mg/L, which was never recorded in these wetlands.
11. Inorganic phosphorous showed seasonal variations in all the three wetlands. Increased values during summer were found to be mainly due to regeneration of inorganic phosphorus from the bottom sediments during decomposition. Statistically, PO_4-P was found to be directly related with phytoplankton and inversely with zooplankton.
12. Among nitrogenous compounds, nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), and ammonia-nitrogen (NH_3-N) were detected. NO_3-N showed wide seasonal fluctuations and found to be inversely related with phytoplankton. NO_2-N occurred in fairly good amounts and showed seasonal fluctuations. It varied from 0.018 mg/L to 0.580 mg/L during different months of the study. The main sources of nitrate-nitrogen and nitrite-nitrogen were found to be sewage discharge, fertilizers used in the adjoining agricultural fields, decaying vegetables and other waste matter. Concentration of these substances was also found to be dependent on the relative abundance of nitrifying and denitrifying organisms and their activities.

13. Higher concentrations of NH_3-N during summer, monsoon and post-monsoon months were found to be due to decaying organic matter and high temperature during the period. It showed negative correlation with phytoplankton at CP-1 and CP-2 and positive at MP.
14. Silica, another important nutrient required for the production and growth of *diatoms* and *chrysophyceans*, occurs in quite good amounts in these wetlands. It showed wide seasonal variations and exhibited inverse relationship with diatoms at CP-1 and CP-2.
15. Dissolved nutrients were always found in appreciable amounts and indicate eutrophic nature of these wetlands.
16. Plankton, both phyto and zooplankton, are well represented in these wetlands, sometimes showing water blooms of certain *blue-green algae*.
17. Phytoplankton are represented by 27 genera and comprised of five major groups, which in order of abundance are *Chlorophyceae* > *Myxophyceae* > *Bacillariophyceae* > *Euglenophycea* > *Desmidiaceae.* Generally, higher densities of phytoplankton were found during post-monsoon, winter and summer months. Certain genera were found to disappear at certain periods and reappear during the periods of favourable conditions.
18. Zooplankton are represented by 22 genera and comprised of four major groups, namely *Rotifera, Cladocera, Copepoda* and *Ostracoda.* Their population showed nearly the same trend as that of phytoplankton. Copepods were found to be comparatively less abundant than that of *Cladodcerans* and *Rotifers* but higher than that of *Ostracods. Rotifers* are represented by *Brachionus* spp., *Keratella* spp., *Notholca* sp., *Filinia* sp., *Testudinella* sp. and *Asplanchna* sp. *Filinia* sp. being an important representative of eutrophic water bodies was found in almost all the samples collected from these wetlands. *Cladodceran* richness was found to be quite moderate and about 10 species were observed in these wetlands.
19. Eggs and Nauplier stages of zooplankton were also encountered throughout the study period, except in few months, which indicate that the reproduction is carried out throughout the year.

20. The wetlands were also found inhabited by certain fishes, like *Esomus danricus*, *Clarias batrachus*, *Heteropneustes fossilis*, *Puntius sophore* and *Colisa fascitus*, aquatic insects, frogs, toads, water snakes, worms, tortoises, and variety of macrophytes.
21. These wetlands were found to be highly productive showing peaks during summer and post-monsoon seasons. However, seasonal fluctuations in the primary production show that the production rate does not remain same throughout the year as reported by other workers. Higher rates, as compared to reported ones, indicate that these wetlands are primarily rich in nutrients with enough lighted zone and energy content.
22. Chlorophyll 'a' showed significant direct relationship with G.P.P. and N.P.P.

RECOMMENDATION

On the basis of the above mentioned findings, these wetlands, being productive in nature and free from pollution load except sewage input, can very well be used intensively for pisciculture or even for integrated fish farming after following the modern technology used and recommended by CIFA, Kaushalyagang, Bhubneshwar for their proper management.

Important: Since the wetlands were found to be disturbed throughout the periods of investigations, most of the statistical data showed non-significant results. Disturbances are usually caused by human activities like daily washing of live stocks, cast-net fishing, washing clothes by the local people at regular intervals and also due to use of water for bathing and other recreational purposes

Chapter VII

REFERENCES

REFERENCES

Adams, G.D. (1988) Wetlands of the prairies of Canada. *In. Wetlands of Canada.* National wetlands working group. Ecological land classification series, No. 24. Sustainable development Branch, Environment Canada, Ottawa, Ontario, Canada and Polyscience Publications Inc., Monteral, Quebec, Canada, 158-198.

Adamus, P.R. (1992) Choices in monitoring wetlands. *In. Ecological Indicators.* (Ed. D.H. McKenzie, D.E. Hyatt and V.J. McDonald). Elsevier Applied Science, London, UK, 571-592.

Adamus, P.R. (1996) Bioindicators for assessing ecological integrity of prairie wetlands. U.S. Environmental Protection Agency, Western Ecology Division, Corvallis, or U.S.A. EPA/600/R-96/082.

Adamus, P.R. and Stockwell, L.T. (1983) *A Method for Wetland Functional Assessment: Critical Review and Evaluation Concepts.* Vol. 1. U.S. Department of Transportation, Federal Highway Administration, Report FHWA-IP-82-23, Washington D.C., 176pp.

Agarwal, A. and Chak, A. (1991) Floods, Flood planis and Environmental Myths. *In. State of India's Environment: A Citizen's Report.* Centre for Science and Environment, New Delhi.

Agarwal, N.C., Bais, V.S. and Tazeen, A. (1995) Comparative accounts of phytoplankton productivity in the Sagar Lake and the Military Engineering Lake: Statistical approach. *J.Freshwater Biol.*, 7(1): 27-32.

Alabaster, J.S. and Lloyd, R. (1984) *Water Quality Criteria for Fresh Water Fish.* 2nd ed. Butterworths, London, 361pp.

Alam, A., Khan, A. A., Parveen, S. and Untoo, S.A (2002b) Morphological variations in a Brachionid Rotifer, *Brachionus bidentatus* (Anderson). *In. Wetlands Conservation and Management.* (Ed. B.B. Hosetti) Pointer Publishers Jaipur, (Raj.) India, 142-150.

Alam, A., Khan, A.A., Untoo, S.A. and Parveen, S. (2002a) *Asplanchna* Induced phenotypic plasticity in *Brachionus calyciflorus* and its adaptive significance: A laboratory approach. *In. Ecology and Ethology of Aquatic Biota* (Ed. A. Kumar). Daya Publishing House, Delhi, India, 294-298.

Alam, M.J., Habib, M.A.B. and Begum, M. (1989) Effect of water properties and dominant genera of phytoplankton on abundance of available genera of zooplankton. *Pak. J. Sci. & Res.*, **32**: 194-200.

Ali, M. and Khan, A.A. (1979) Limnological studies on sewage fed pond of Aligarh. *Science & Environment* **10**(2): 1985-1991.

Alikuni, K.H. (1957) Fish culture in India. *Farm Bulletin*, New Delhi 20 ICAR, 126pp.

Allan, J.D. (1976) Life history patterns in zooplankton. *Am. Nat.* **110**: 165-180.

Anantharaj, B., Bagyalakshmi, V. and Lakshmi, R. (1987) Limnology of river Cooum with special reference to sewage and heavy metal pollution. *Proc. Indian Acad. Sci.*, Sec. B., **96**(2): 141-149.

ANCA (1996) *A Directory Of Important Wetlands In Australia*, 2nd Ed. Australian Natrure Conservation Agency, Canberra.

Anderson, D.V. (1964) The thermal regime of lake simcoe. *Technical Series, Research Report* No. 57.

Anderson, D.V. (1968) Nocturnal heat loss of a lake and seasonal variation in its thermal structure. *Bulletin of the I.A.S.H.*, **13**(3): 33-40.

Anderson, G.C. (1960) Recent changes in the trophic nature of lake Washington: A review. *Rep. Trans.* Seminar on algae and metropolitan wastes, U.S. Public Health Service, *R.A.T. Sanit. Engy. Centre*, Cincinnati, Ohio.

Anderson, R.S. (1971) Crustacean plankton of 146 Alpine and Subalpine lakes and ponds in western Canada, *J. Fish. Res. Bd. Canada*, **28**: 311-321.

Anderson, R.S. (1974) Crustacean plankton communities of 340 lakes and ponds in and near the national park of the Canadian Rocky Mountains. *J. Fish. Res. Bd. Canada*, **31**: 855-869.

Anon (1986) Water management plan for the Macquarie Marshes, New South Wales Water Resources Commission, Sydney, 23pp.

Anon (1989) Limnology and production biology of two man-made lakes in Rajasthan, India with management strategies for their yield and utilisation. Final Report of IDA Assisted Pilot Project on Reservior Management in Rajasthan, CIFRI, Barrackpore.

Anon (1995) Draft water management plan for the Macquarie Marshes. New South Wales National Parks and Wildlife Service. Hustville, Australia and New South Wales Department of Land and Water Conservation, Dubbo, Australia, 35pp.

Anonymous (1975) Proposals for a standization of diatom terminology and diagnoses. *Nova Hedwigia*, **53**: 323-354.

APHA (1992) *Standard Methods for Examination of Water and Wastewater*. 18^{th} ed., American Public Health Association, AWWA, WPCF, Washington, D.C.

Arora, H.C. (1961) Rotifers as indicators of pollution. *Bull. CPHERI*, **3**: 24pp.

Arora, H.C. (1966) *Rotifera* as indicators of trophic nature of environments. *Hydrobiologia,* **27**(1-2): 146-149.

Arora, B.R., Azad, A.S., Singh, B. and Sekhon, G.S. (1985) Pollution potential of municipal waste waters of Ludhiana, Punjab. *Indian J. Ecol.*, **12**(1): 1-7.

Arnott, S.E., Magnuson, J.J. and Yam, N.D. (1988) Crustacean zooplankton species richness: Single and multiple year estimates. *Can. J. Fish Aquat. Sci.*, **55**: 1573-1582.

Atkins, R.P., Congden, R.A., Finlayson, C.M. and Gordon, D.M. (1977) Lake Leschenaultia: An oligotrophic artificial lake in Western Australia. *J. Royal Soc. Western Aus.*, **59**: 65-70.

Atkins, W.R.G. (1923) The silica content of some natural waters and of culture media. *J.Mar. Biol. Ass.*, U.K. **13**: 151-159.

Atkins, W.R.G. (1932) Solar radiation and transmission through air and water. *J. Couns. Int. Expl. Mel.*, **7**: 171-211.

Atkinson, K.M. (1972) Birds as transporters of algae. *British Phycological J.*, **7**: 319-321.

Ayyappan, S. and Gupta, T.R.C. (1981) Limnology of Ramansamudra Tank. *J. Inland Fish Soc. India,* **12**(2): 1-12.

Ayyappan, S. and Gupta, T.R.C. (1981a). Limnology of Ramasamudra Tank: Hydrography. *Mysore J. Agri. Sci.*, **14**: 408-420.

Ayyappan, S. and Gupta, T.R.C. (1985) Limnology of Ramasamudra Tank: Primary production. *Bull. Bol. Soc. Sagar, India,* **32**: 82-85.

Babu, G.S., Hans, R.K., Singh, J., Vishvanath, P.N. and Joshi P.C. (2001) Effect of Lindane on the growth and metabolic activities of cyanobacteria. *Ecotoxicol. Environ. Safety*, **48**: 219-221.

Bais, V.C., Agarwal, N.C. and Shukla, S.N. (1993) Effects of Microcystis bloom on the density and diversity of the cyanophyceae population in Sagar lake. *Proc. Acad. Env. Biol.*, **2**(1): 17-23.

Barclay, M.H. (1966) An ecological study of a temporary pond near Auckland, New Zealand . *Aust. J. Mar. Freshw. Res.*, **17**: 1-30.

Bardecki, M.J. (1984) *Wetland Conservation Policies in South Ontario: A Delphi Approach.* Ph.D. Thesis, York University, Toronto, Geographical Monographs, No. 16.

Barnes, H. (1959) *Apparatus and Methods of Oceanography.* Part I *Chemical.* George Allen and Unwin Ltd., 341pp.

Barson, M.M. and William, J.E. (1991) Wetland inventory: Towards a unified approach. *Bureau Rural Resource*, Canberra.

Baruha, A., Sinha, A.K. and Sharma, U.P. (1993) Plankton variability of a tropical wetalnd, Kawar, Beghusarai, Bihar, India. *J. Freshwater Biol.*, 5: 27-32.

Battish, S.K. (1992) *Freshwater Zooplankton of India.* Oxford and IBH Publishing Co., Pvt. Ltd. New Delhi.

Beauchamp de., P. (1965) Classe des Rotifers. *In*: *Traite de Zoologie* (Ed. P.P. Grasse), Paris. **4**(3): 1225-1379.

Beeton, A.M. (1958) Relationship between secchi disc reading and light penetration in lake Wiscon. *Trans. Amer. Fish. Soc.*, **87**: 73-79.

Bell, H.L. (1971) Effect of low pH on the survival and immergence of aquatic insects. *Water Res.*, **5**: 313pp.

Bernice, A., Bagyalakshmi, V. and Lakshmi, R. (1987) Limnology of river Cooum with special reference to sewage and heavy metal pollution. *Proc. Indian Acad. Sci. Sec* (B), **96**(2): 141-149.

Berst, A.H. and McCrimmon, H.R. (1966) Comparative summer limnology of Innee Long Point Bay, Lake Erie and its major tributaries. *J. Fish. Res. Bd. Canada,* **23**(2): 275-291.

Berzins, B. and Pejler, B. (1987) Rotifer occurrences in relation to pH. *Hydrobiologia*, **147**: 107-116.

Bhandary, B. (1993) the current status of wetlands in Nepal. *In. Towards Wise Use of Asian Wetlands: Proceedings of Asian Wetland Symposium,* (Eds. H. Isozaki, M. Ando and Y. Natori) 15-20October, 1992, Otus and Kushiro, Japan, International Lake Committee Foundation, Kusatsu City, Shiga 525, Japan.

Bharati, S.G. and Hosmani, S.P. (1975) Limological studies in ponds and lakes of Dharwad. III. Occurrence of two *Euglenoid* blooms. *J. K. Uni. Sci.*, **20**: 353-382.

Bhatt, S.D. and Negi, U. (1985) Physico-Chemical features and phytoplankton in subtropical pond. *Comp. Physiol. Ecol.* **10**(2): 85-88.

Bhatt, S.D. and Pathak, J.K. (1992) Assessment of water quality and aspects of pollution in a stretch of River Gomti (Kumaun: Himalaya). *J. Environ. Biol.*, **13**: 113-126.

Biggs, B.J.F. (2000) Eutrophication of streams and rivers: Dissolved nutrients-chlorophyll relationships for benthic algae. *J. North Amer. Benthological Soc.*, **19**: 17-31.

Birge, E.A. (1916) The work of wind in warming lake. *Trans. Wes. Acad. Sci. Arts Lett.*, **18**: 341- 391.

Birge, E.A. (1918) The Water Fleas (Cladocera). *In. Freshwater Biology.* (Ed. W.T. Edmondson). John Wiley and Sons, New York, **22**: 676-740.

Birge, E.A. and Juday, C. (1911) The inland Lake Wisconsin. The dissolved gases and their biological significance. *Bull. Wis. Geol. Nat. Hist. Surv.*, **22**: 259pp.

Birge, E.A. and Juday, C. (1929) Transmission of solar radiation by the water of inland lakes. *Trans. Wis. Acad. Sci. Arts. Lett.*, **24**: 509-580.

Birsal, N.R. (1996) The primary productivity of the Supa reservoir during its filling phase. *J. Envi. Biol.*, **17**(2): 127-132.

Bisht, R.S. and Das, S.M. (1985) Abiotic parameters and aquatic insects of two cold water Kumaon Lakes. *Ind. J. Ecol.*, **12**: 365-369.

Biswas, B. and Trisal, C.L. (1993) Intiatives for the conservation of Wetlands in India. *In. Biodiversity Conservation: Forests, Wetlands and Deserts.* (Eds. B. Frame, J. Victor and Y. Joshi), Tata Energy Research Institute, New Delhi, 47-53.

Blair, D. and Finlayson, C.M. (10981) Observations on the habitat and biology of a Lymnaeid snail, *Astropeplea vinosa* (*Gastropoda*: *Pulmonata*): An intermediate host for avian schistosomes in tropical Australia. *Aust. J. Mar. Fresh. Res.*, **32**: 757-767.

Bogdan, K.G. and Gilbert, J.J. (1982) Seasonal patterns of feeding by natural populations of *Keratella, Polyarthra* and *Bosmina,* clearance and community grazing. *Limnol. Oceanogr.*, **27**(5) : 981-934.

Bohra, C. and Kumar, A. (2002) Primary productivity of a sewage fed aquatic ecosystem. *In. Ecology and Ethology of Aquatic Biota.* (Ed. A. Kumar) Daya Publishing House, Delhi, 373-392.

Bohra, O.P. (1976) *Some Aspects of Limnology of Padmasagar and Ranisagar.* Ph.D. Thesis. Jodhpur University, Jodhpur, India.

Bohra, O.P., Misra, S.D. and Bhargava, S.C. (1978) Ocutrance of a thermocline in two lakes of semi arid region in Western Rajasthan. *Hyrobiologia*, **9**: 203-211.

Bolen, E.G, Smith, L.M. and Schramm, H.L. (1989) Playa Lakes: Prairie wetlands of the Sothern high plains. *Biosci.*, **39**: 615-623.

Bomber, J.W., Guillard, R.R.L. and Nelson, W.G. (1988) Role of temperature, salinity and light in seasonality, growth and toxicity of ciguatera-causin *Gambierdiscus toxicus* Adachi et Fukuyo (Dinophyceae). *J. Exp. Mar. Biol. Ecol.*, **115**(1): 53-65.

Boutin, C. and Keddy, P.A. (1993) A functional classification of wetland plants. *J. Veg. Sci.*, **4**: 591-600.

Boyd, C.E. (1990) *Water Quality in Pond for Aquaculture*. Brimingham Publishing Co., Alabama, USA, 428pp.

Brett, M.T. (1989) Zooplankton communities and acidification processes: A review. Water, air and soil pollution., **44**: 387-414.

Brock, T.D. amd Brock, M.L. (1968) Relationship between environmental temperature and optimum temperature of bacteria along a hot spring thermal gradient. *J. Appl. Bact.*, **31**: 54-58.

Bronk, D.A., Glibert, P.M., Malone, T.C., Banaham, S. ansd Sahlsten, E. (1998) Inorganic and organic nitrogen cycling in Chesapeake Bay: Autotrophic verses heterotrophic processes and relationship to carbon flux. *Aquat. Microbol. Ecol.*, **15**: 117-189.

Brown, R.M., Larson, D.M. and Bold, H.C. (1964) Airborne algae: their abundance and heterogeneity. *Sci.*, **143**: 583-585.

Buesa,.R.J. (1975) Population biomass and metabolic rates of marine angiosperms on the northwestern Cuban shelf. *Aquatic Botany*, **1**: 11-23.

Bunn, S.E., Boon, P.I., Brock, M.A. and Schofield, N.J. (1997) National Wetlands R&D Progrramme: Scooping review. Land and water Resource Research and development Corporation, Canberra, Australia.

Burns, C.W. and Rigler, F.H. (1967) Comparison of filtering rates of *Daphina rosea* in lake water and suspensions of yeast. *Limnol. Oceanog.*, **14** : 429-502.

Cairns, J. (1974) Indicator species vs the concept of community structure as an index of pollution. *Water Resour. Bull.*, **10**(2): 338-347.

Cairns, J., Lanza, G.R. and Parker, B.C. (1972) Pollution related structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa. *Proc. Acad. Nat. Sci. Phil.*, **124**(5): 7-127.

Cairns, J. and Prant, J.R. (1993) A history of biological monitoring using benthic macroinvertebrates. *In. Freshwater Biomonitoring and Benthic macroinvertebrates*. (Eds. D.M. Rosenberg and V.N. Resh) Chapman and Hall, New York, 10-27.

Canfield Jr., D.E. (1983) Prediction of chlorophyll 'a' concentrations in Florida Lakes: The importance of phosphorous and nitrogen. *Wat. Res. Bull.*, **19**: 255-262.

Carmichael, W.W. (1996) Toxic *Microcystis* and the environment. *In. Toxic Microcystis*. (Eds. M.F. Watanabe, K. I. Harada, W.W. Carmichael and H. Fujiki). CRC Press, Boca Raton, 1-11.

Carmichael, W.W. (1998) *Microcystis* concentration in human livers: Estimation of human lethal dose: Lessons from Caruaru, Brazil. *4th International Conference on Toxic cyanobacteria. Beaufort, North Carolina*, USA.

Carpenter, S.R. and Kitchell, J.F. (1993) *The Trophic Cascade in Lakes*. Cambridge University Press, Cambridge, UK.

Carter, J.C.H. (1971) Distribution and abundance of planktonic crustacea in ponds near Georgian Bay, Ontario, Canada in relation to hydrography and water chemistry. *Arch. Hydrobiol.*, **68** :204-231.

Carter, V. and Rybicki, N.B. (1985) The effects of grazers and light penetration on the survival of the transplants of *Vallisneria americana* Michx. in the tidal Potomac River, Maryland. *Aquatic Botany*, **23**: 197-213.

Carter, V. and Rybicki, N.B. (1991) Effects of submerged macrophytes on dissolved oxygen, pH, and temperature under different conditions of wind, tide, and bed structure. *J. Freshwater Ecol.*, 6(2): 121-133.

Cathartic, T.P. and Wheaton, F.W. (1987) Modeling temperature distribution in freshwater pond. *Aquacultural Engineering*, **6**: 237-257.

CEEP (Centre European d'Etudes des Polyphosphates) (2001) Phosphate Recovery: Recycling: A reality, as yet smallscale. Phosphates and Potash (P.K.). Insight special clear water issue/supplement. Av. E. van Nieuwenhuyse 4, bte 2 B1160 Bruxelles, Belgium, 5pp.

Chacko, P.I. and Ganapati, S.V. (1949) Some observations of the Adyar river with special reference to its hydrobiological conditions. *Indian Geogr. J.*, **3**: 1-15.

Chacko, P.I. and Krishnamoorthy, B. (1954) On the plankton of three freshwater fish ponds in Madras city, India. *In*: Symposium on marine and freshwater plankton in Indo-Pacific. *Indo-Pacific Fish. Coun.*, (UNESCO) 103-107.

Chakrabarty, R.D., Ray, P. and Singh, S.B. (1959) A quantitative study of the plankton and the physico-chemical conditions of the river Jamuna at Allahabad in 1954-55. *Indian J. Fish.*, **6**(1): 186-203.

Chambers, P.A. and Kalff, J. (1985). Depth distribution and biomass of submersed aquatic macrophytes communities in relation to Secchi depth. *Can. J. Fish. Aquat. Sci.,* **42**: 701-709.

Chambers, P.A. and Prepas, E.E. (1988) Underwater spectral attenuation and its effect on the maximum depth of angiosperm colonization. *Can. J. Fish. Aquat. Sci.,* **45**:1010-1017.

Champ, M.A., Gould, G.A. III, Bozzo, W.E., Ackleson, S.G. and Vierra, K.C. (1980). Characterization of light extinction and attenuation in Chesapeake Bay, August 1977. *In.* Estuarine Perspectives. (Ed. V.S. Kennedy). Academic Press, New York, 263-277.

Chandler, D.C. (1944) Limnological studies of western lake Erie. IV. Relation of Limnological and climatic factors to the phytoplankton of western lake Erie. *Trans. Amer. Microse. Soc.,* **63**: 203-236.

Chatrath, K.J.S. (1992) The challenges of Chilka. *In. Wetlands Of India.* (Ed. K.J.S. Chatrath) Ashish Publishing House, New Delhi, India.135-170.

Chatrath, K.J.S. (1992a) *Wetlands Of India.* Ashish Publishing House, New Delhi, India.171pp.

Chattopadhya, S.N., Rauth, T., Sharma, V.P., Arora, H.C. and Gupta, R.K. (1984) A short term study on the pollution status of a River Ganga in Kanpur region. *Indian J. Environ. Hlth.*, **26**(3): 244-257.

Chaudhuri, A.B. (1998) *Wetland Ecology: Resources, Research and Conservation: An Indian scenario.* (Ed. A.B. Chaudhuri) MESP Publishers, Nadia, West Bengal, India, 379pp.

Cheng, L. (1976) *Insects in Marine Environments.* North Holland Publishing Co. Amsterdam, 581 pp.

Chiang, S. C. and Du, N.S. (1979) Freshwater Cladocera: Fauna Sinica, 6, *Crustacea.* Academia Sinica, Science Press, Peking. 297pp.

Chen Sou-Chang (1965) Seasonal abundance of Copepoda in Lake Tungh-Wu-shown by data obtained in the course of one year. *Acta. Hydrobiol. Sin,* **5**: 202-219.

Chourasia, S.K. and Adoni, A.D. (1985) Zooplankton dynamics in a shallow entrophic lake. *In. Proc. Nat. Symp. Pure and Appl. Limnology.* (Ed. A.B. Adoni). *Bull. Bot. Soc. Sagar, India,* **32**: 30-39.

Clarke, G.L. (1941) Observations on transparency in souh western section of the North Atlantic Ocean. *J. Mar. Res.*, **4**: 221-230.

Cole, G.A. (1983) *Textbook of Limology.* (3rd ed.). The C.V. Mosby Company, London, 401 pp.

Cole, J.J., Caraco, N.F., Kling, G.W. and Kratz, T.K. (1994) Carbondioxide supersaturation in the surface waters of lakes. *Science*, **265**: 1568-1570.

Comita, G.W. (1985) The seasonal primary productivity cycles, their normal distribution and the associated chemical and physical cycles in a freshwater impoundment. *Arch. Hydrobiol. Suppl. Biol.*, **72**(1): 1-48.

Conger, D.H. (1971) Estimating magnitude and frequuency of floods in Wisconsin. *U.S. Geog. Survey*. Open-File Report, Madison, Wisconsin, 200pp.

Conley, D.J. (2000) Biogeochemical nutrient cycles and nutrient management strategies. *Hydrobiologia*, **410**: 87-96.

Conley, D.J. and Malone, T.C. (1992) Annual cycle of dissolved silicate in Chesapeake Bay: Implications for the production and fate of phytoplankton biomass. *Mar. Ecol. Prog. Ser.*, **81**: 121-128.

Conley, D.J., Schelske, C.L. and Stoermer, E.F. (1993) Modification of silica biogeochemistry with eutrophication in aquatic systems. *Mar. Ecol. Prog. Ser.*, **101**: 179-192.

Conover, R.J. (1961) A study of Charles Town and Green Hill Ponds, Rhodes Island. *Ecology*, **42**(1): 119-140.

Cooke, G.D., Welch, E.B., Peterson, S.A. and Newroth, P.R. (1993) *Restoration and Management of Lakes and Reservoirs*. 2nd ed., Lewis Publishers, Bocca Raton, 548pp.

Cowardain, L.M., Carter, V., Golet, F.C. and La Roe, E.T. (1979) *Classification of Wetlands and Deepwater Habitats of the United States*. U.S. Department of the Interior. Fish and Wild Life Service, Washington D.C., 131pp.

Crease, T.J. and Taylor, D.J. (1998) The origin and evolution of variable-region helices in V4 and V7 of small-subunit ribosomal RNA of Branchiopod Crustaceans . *Molecular Biol. Evol.*, **15**(11): 1430-1446.

Croll, D.A. and Holmes, R.W. (1982) A note on the occurance of diatoms on the feathers of diving seabirds. *Auk*, **99**: 765-766.

Cucker, B.E. (1997) Field experiment on the influence of suspended clay and P on the plankton of a small lake. *Limnol. Oceangr.*, **32**: 840-847.

Czernas, K. (1991) Preliminary investigations on vertical differentiation of primary productivity of Eupsammon and Hydropsammon in Polish. *Stud. Ooerod. Dokument Fizjograf PAN Krakow*, **9**: 393-400.

Czernas, K. (2001) Productivity of the psammic algae communities in the near-shore zone of Mesotrophic Lake Piaseczno (Eastern Poland). *Water Qual. Res. J.* Canada, **36**(3): 537-564.

Dadswell, M.J. (1974) Distribution ecology and post-glacial dispersal of certain crustacea and fishes in eastern North America, *Nat. Mus. Nat. Sci. Publ. Zool.*, **11**: 1-110.

Das, A.K. (2000) Limno-chemistry of some Andhra Pradesh reservoirs. *J. Inland Fish. Soc. India*, **32**(2): 37-44.

Das, S.K., Bhattacharjya, B.K. and Goswami U.C. (2001) Diel variation of pH in fish ponds of Nawgaon, Assam. *J. Inland Fish. Soc.* India, **33**(1): 45-48.

Das, S.M. (1970) Organic production in Kashmir Lakes. IBP (PF) Report, Symposium in Poland, **1**: 67-75.

Das, S.M. and Srivastava, D.K. (1956) Quantitative study on freshwater plankton: Plankton in a fish tank in Lucknow, India. *Pro. Nat. Acad. Sci., India*, **26**: 85-96.

Das, S.M. and Srivastava, V.K. (1959) Studies on frehwater plankton. III. Qualitative composition and seasonal fluctuations in plankton components. *Proc. Nat. Acad. Sci., India*, **29**: 174-189.

Dash, G. (2002) Flora, fauna and Fish potential of lentic. waters. *In. Wetlands Conservation and Management.* (Ed. B.B. Hosetti) Pointer Publisher Jaipur, India, 88-103.

Datta, N.C. and Bandhopandhayay, B.K. (1985) Rotifers as bioindicators of the state of aquatic environment. Symp. *Biomonitoring State Environ.*, 159-166.

Datta, N.C., Bandhyopadhyay, B.K., and Mandal, N. (1984) Seasonal variations of primary productivity in relation to some physico-chemical properties of a freshwater pond, Calcutta. *Indian J. Acad. Ichthyol., Modinagar*, **5**(1-2):113-120.

Datta, N.C., Bandhyopadhyay, B.K., Mandal, N. and Maity, N.C. (1983) Diurnal variation of some abiotic factors and plankton communities in two freshwater ponds at Calcutta. *Environment & Ecology*, **1**: 129-133.

Datta, S. (1999) *Diversity Pattern of Tropical Pond Ecosystem: Nutrient Dynamics And Functional Relationships*. Ph.D. thesis. University of Kalyani, West Bengal, India.

David, E.M. and Robert, T.H. (1979) Functionally distinct classes of complex phosphrous compounds in lake water. *Am. Soc. Limnol. Oceangr.*, **24**(3): 463-473.

Davis, C.C. (1954) A prelimaninary study of the plankton of the Cleveland Harbour area, Ohio. II. The distribution and quantity of the phytoplankton. *Ecol. Monogr.*, **24**: 21-47.

Davis, C.C. (1962) The plankton of the Cleveland Harbour area of Lake Erie in 1956-1957. *Ecol. Monogr.*, **32**: 209-247.

Davis, S.N. (1964) Silica in streams and ground water. *Amer. J. Sci.* **262**: 870-891.

Davis, T.J. (1994) *The Ramsar Convention Manual: A Guide to the Convention on Wetlands of International Importance Especially as Waterfowl Habitats.* Ramsar Convention Bureau, Gland, Switzerland.

Day, F. (1958) *The Fishes of India: Natural history of the fishes known to inhabit the seas and fresh waters of India, Burma and Ceylon.* Vol. 1 and 2. William Dawson and Sons Ltd., London 777pp.

Dayananda, G.Y., Phatak, S. and Hosetti, B.B. (2002) Studies on water quality of Gudavi Wetlands. *In. Wetlands Conservation and Management.* (Ed. B.B. Hosetti) Pointer Publisher Jaipur, India.266-297.

DeManuel, J. (1994) Taxonomic and zoogeographic considerations on Lecanidae (Rotifera: Monogonota) of the Balearic archipelago, with description of new species, *Lecane margalefin* Sp. *Hydrobiologia*, **288**: 97-105.

DeRoy, R. (1992) Case study of Loktak Lake of Manipur. *In. Wetlands of India.* (Ed.K.J. Chatrath). Ashish Publishing House, New Delhi, 37-70.

DeRoy, R. and Thadani, R. (1992) *India's Wetlands: Mangroves and Coral reefs.* WWF-India, N. Delhi, 61pp.

DeRoy. R. and Hussain, S.A. (1993) *Directory of Indian Wetlands.* WWF-India, New Delhi, India, and Asian Wetalnd Bureau, Kuala Lumpur, Malayasia.

DeSilva, S. (1988) *Reservoirs of Srilanka and their fisheries.* F.A.O. Tech. Paper-298.

De Smet, W. H. (1995) *Rotifera.* III. The *Notommatidae* and *Scaridiidae. In. Guide to the Identification of Microinvertebrates of Continental Waters of the World.* (Eds. H.J. Dumont and T. Nogrady) (8), SPB Academic Publishers, Amsterdam, The Netherlands.

De Smet, W. H. (1996) *Rotifera*. IV. The *Proalidae* (Monogononta). *In. Guide to the Identification of Microinvertebrates of Continental Waters of the World.* (Eds. H.J. Dumont and T. Nogrady) (8), SPB Academic Publishers, Amsterdam, The Netherlands.

De Smet, W. H. and Purriot, R. (1996) *Rotifera*. V. The *Dicranophoridae Monogonta* and the Ituridae. *In. Guides to the Identification of Microinvertebrates of Continental Waters of the World.* (Eds. H.J. Dumont and T. Nogrady) (12), SPB Academic Publishers, Amsterdam, The Netherlands.

Deb, D., Ghosh, M. and Banergee, S. (1987) Synecology of a rotifer bloom in a freshwater pisciculture pond in West Bengal. *Proc. Indian Natn. Sci. Acad.*, **B 53**(1): 61-68.

Dennison, W.C. (1987) Effects of light on Seagrass photosynthesis, growth and depth distributions. *Aquatic Botany,* **27**: 15-26.

Dennison, W.E. and Alberte, R.S. (1982) Photosynthetic response of *Zostera marina* L. (Eelgrasss) to *in-sito* manipulations of light intensity. *Oecologia.*, **55**: 137-144.

Dennison, W.E. and Alberte, R.S. (1985) Role of daily light period in the depth distribution of *Zostera marina* L. (Eelgrasss). *Mar. Ecolo. Prog. Series.* **25**: 51-61.

Dennison, W.E. and Alberte, R.S. (1986) Photo-adaptations and growth of *Zostera marina* L. (Eelgrasss) transplants along a depth gradient. *J. Exp. Marine Biol. Ecol.,* **98**: 265-282.

Deppe, T., Ockenfeld, K., Meybohm, A., Opitz, M. and Benndorf, J. (1999) Reduction of *Microcystis* bloom in a hypertrophic reservoir by a combined ecotechnological strategy. *Hydrobiol*ogia, **408/409**: 31-38.

Dhamija, S.K. and Jain, Y. (1994) Variations in the physico-chemical characteristics of lentic waterbody of Jabalpur (M.P.). *J. Envi. Poll.*, **1**(3-4): 125-128.

Dhamija, S.K. and Jain, Y. (1995) Studies on the water quality index of a lentic waterbody at Jabalpur (M.P.) *Poll. Res.,* **14**(3): 341-346.

Dodds, W.K. (1997) Distribution of runoff and rivers related to vegetative characteristics, latitude and slope: A global perspective. *J. North Amer. Benthological Soc.*, **16**: 162-168.

Dodds, W.K., Blair, J.M., Henebry, G.M., Koelliker, J.K., Ramundo, R. and Tate, C.M. (1996) Nitrogen ttransport from Tallgrass Praire watershed. *J. Environ. Qual.*, **25**(5): 973-981.

Dodds, W.K., Jones, J.R. and Welch, E.B. (1998) Suggested criteria for stream trophic state: Distributions of temperate stream types by chlorophyll, total nitrogen and phosphorous. *Water Res.*, **32**: 1455-1462.

Dodds, W.K., Smith, V.H. and Zander, B. (1997) Developing nutrient targets to control benthic chlorophyll levels in streams: A case study of the Clark Fork River, *Water Res.*, **31**: 1738-1750.

Dodds, W.K. and Welch, E.B. (2000) Establishing nutrient criteria in streams. *J. N. Am. Benthol Soc.*, **19**(1): 186-196.

Dodson, S.I. (1992) Predicting crustacean zooplankton species richness. *Limnol. Oceanogr.*, **37**: 848-856.

Dodson, S.I. (1974) Zooplankton competition and predation: an experimental test of the size- efficiency hypothesis. *Ecology*, **55**:605-613.

Dodson, S.I. (1989) Predation of *Heterocope septentrionalis* on two species of *Daphnia*: Morphological defenses and their cost. *Ecology*, **65**: 1249-1257.

Dodson, S.I. and Frey, D.G. (1991) Cladocera and other Branchiopoda. *In. Ecology and Classification of North American Freshwater Invertebrates*. (Eds. J.H. Thorpe and A.P. Covich). Academic Press, New York, 723-786.

Doering, P.H., Oviatt, C.A., Bealty, L.L., Banzon, V.F., Rice, R., Kelly, S.P., Sullivan, B.K., and Frithsen, J.B. (1989) Structure and function in a model coastal ecosystem: Silicon, the benthos and eutrophication. *Mar. Ecol. Prog. Ser.*, **52**: 287-299.

Donner, J. (1965) Ordnung Belloidea (Rotatoria, Rädertiere). Best. Bucher Z. Bodenfauna Europas, Berlin 6: 1-297.

Dortch, Q., Milsted, D., Rabalais, N.N., Lohrenz, S.E. Redalje, D.G. Dagg, M.J., Turner, R.E., and Whiteledge, T.E. (1992) Role of silicate availability in phytoplankton species composition and the fate of carbon. *Proc. NOAA, Nutrient Enhanced Coastal Ocean Productivity Program Synthesis Meeting, LUMCON*, Oct., 1991. Taxas Sea Grant, Technical Publication TAMU-SG-92-108, College Station, 76-83.

Downing, J.A., and McCauley, E. (1992) The N : P relationship in lakes. *Limnol. Oceanogr.*, **37**: 936-945.

Duarte, C.M. (1995) Submerged aquatic vegetation in relation to different nutrient regimes. *Ophelia*, **41**: 87-112.

Dubey, J. and Gupta, R. (1993) Periphytic algae growth on natural and artificial substrates in Sagar Lake. *Geobios News Rept.*, **12**: 132-136.

Dudani, V.K., Kumar, S. and Pandey, S. (1988) Gastropods as indicators of the trophic status of some ponds I Darbhanga, N. Bihar., *Proc. Nat. Acad. Sci., India*, B. **58**: 489-493.

Dugan, P.J. (1990) *Wetland conservation: A Review of Current Issues and Required Action.* IUCN, The World Conservation Union, Gland, Switzerland, 96pp.

Dugan P.J. (1994) Wetlands in the 21th Century: The challenges to conservation science. *In: Global Wetlands: Old world and New World.* (Ed. W.J. Mitsch). Elseviar, Amersterdam, 75-87.

Dumont, H.J. (1980) Zooplankton and science of biography: the example of Africa. *In.Evolution and Ecology of Zooplankton Communities,* (Ed.W.C. Kerfoot), University Press of New England, Hanover, New Hempshre: 685-696.

Dumont, H. J. (1994) On the diversity of the cladocera in the tropics. *Hydrobiologia,* **272**: 27-38.

Dumont, H. J. and Pensaert, J. (1983) A revision of the Scapholeberinae (Crustacea, Cladocera). *Hydrobiologia,* **100**: 3-45.

Dussart, B.H. and Defaye, D. (1985) *Copepoda*: Introduction to the *Copepoda. In. Guide to the Identification of the Microinvertebrates of the Continental Waters of the World.* Vol. 7. SPB Publishers, The Hague, 277pp.

Dussart, B.H. and Fernando, C.H. (1985) Les Copepodes en Sri Lanka (Calanoides et Cyclopoides). *Hydrobiologia,* **127**: 229-252.

Edmondson, W.T. (1959) *Ward and Whipple's Freshwater Biology.* 2nd Ed. John Wiley & Sons Inc., New York, 1248pp.

Edwards, A.M. C. and Liss, P.S. (1973) Evidence of buffering of dissolved silicon in freshwater. *Nature.* **243**: 341-342.

Efford, I.E. (1967) Temporal and spatial differences in phytoplankton productivity in Marion lakes. British Columbia. *J. Fish. Res. Bd. Canada* **24**: 2283-2307.

Egge, J.K. and Aksnes, D.L. (1992) Silicate as regulating nutrient in phytoplankton competition. *Mar. Ecol. Prog. Ser.,* **83**: 281-289.

Elbourn, C.A. (1966) Some observations on the food of *Cyclops strennus strennus* (Fisher). *Ann. Mag. Mat. Hist.* **9**(13): 237-308.

Elgmork, K. (1959) Seasonal occurrence of *Cyclops strennus* in relation to environment in small waterbodies in southern Norway. *Folia. Limnol. Scandanavica.* **11**: 196pp.

Ellenberg, H. (1988) Bioindicator and bioindication. *Angewandte Okologie* (1) Stuttgart, Fisher, 226-262.

Ellis, M.M. (1937) Detection and measurement of stream pollution. *U.S. Bur. Fish. Bill.*, **22**: 367-437.

Ellis, M.M., Westfall, B.A. and Ellis, M.D. (1964) *Determination of Water Quality.* Fish and Wild Life Service. U.S. Deptt. Interior Rept., **9**: 122pp.

Ellison, A.M. and Bedford, B.L. (1995) Response of a wetland vascular plant community to disturbance: A simulation study. *Ecol. Applications*, **5**: 109-123.

Eloranta, P. (1982) Seasonal succession of phytoplankton in an ice-free pond warmed by thermal power plant. *Hydrobiologia,* **86**:87-91.

Eppley, R.W. (1972) Temperature and phytoplankton growth in the sea. *Fish. Bull.*, **70**: 1063-1065.

E.P.A., (1990) Biological criteria: National program guidelines for surface waters. EPA- 440/5-90-004, *Off Water*, Washington, DC.

Fadal, A.A., Metwalli, A. and Houy, F.A.A. (1987) The effect of seasonal variation in temperature and light intensity on the nitrogenous contents in four species of *Chlorophyceae* of Kuwait. *Dirasat Sci.*, **14**(12): 107-118.

Falconer, I.R. (1989) Effects on human health of some toxic cyanobacteria (blue-green algae) in the reservoirs, lakes, and rivers. *Toxicicity Asssessment*, **4**: 175-184.

Falconer, I.R. and Humpage, A.R. (1996) Tumour promotion by cyanobacterial toxins. *Phycologia.*, **35**(Suppl.): 74-79.

Farrell, T.P., Finlayson, C.M. and Griffiths, D.J. (1979) Studies of the hydrobiology of a tropical lake in north-western Queensland. I. Seasonal changes in chemical characteristics. *Aust. J. Mar. Fresh. Res.*, **30**: 579-595.

Fasihuddin, M.D. and Kumari, J. (1990) Seasonal variations in physico-chemical properties and plankton periodicity in a freshwater fish pond at Bhagalpur, India. *Environment & Ecology,* **8**: 929-932.

Fernando, C.H. (1980) The freshwater zooplankton of Sri Lanka, with a discussion of tropical zooplankton composition. *Int. Rev. ges. Hydrobiol.*, **65**: 85-125.

Fernando, C.H. (1994) Zooplankton, fish and fisheries in the tropical freshwater. *Hydrobiologia*, 272: 95-104

Fernando, C.H. and Kanduru, A. (1984) Some remarks on the latitudinal distribution of Cladocera in the Indian subcontinent. *Hydrobiologia*, **113**: 69-76.

Ferris, M.J. and Tyler, P.A. (1985) Chlorophyll- total phosphorus relationships in lake Burrangorang, New south Wales and some other southern hemisphere lakes. *Aust. J.Mar. Fresh. Res.,* **36**: 157-168.

Finlayson, C.M. (1996a) Information required for wetland management in the South Pacific. *In. Wetland Conservation in the Pacific Islands Region.* (Ed. R. Jaench)., Wetlands International - Asia Pacific, Canberra, Publication No. 118, 185-201.

Finlayson, C.M. (1996b) Framework for designing a monitoring programme. *In. Monitoring Mediterranean Wetlands: A Methodological Guide.* (Ed. P. Thomas Vives). Medwet Publication, Wetlands International, Slimbridge, U.K. and I.C.N., Lisbon, 25-34.

Finlayson, C.M. (1996c) *Data Management Systems for Environmental Research in Northern Australia: The Establishment of a Meta-database and Data Management Systems for Wetland Research.* Supervising Scientist Report, Jabiru, Australia.

Finlayson, C.M. (1996d) The Montrux record: A mechanism for supporting the wise use of wetlands. Ramsar Convention, Gland, Switzerland.

Finlayson, C.M. and Gillies, J.E. (1982) Biological and physiological characteristics of the Ross River Dam, Townsville. *Aus. J. Mar. Fresh. Res.*, **33**: 811-827.

Finlayson, C.M. and Larson, T. (1991) *Wetlands Management and Restoration.* Report 3992, Swedish Environmental Protection Agency, Solna, Sweden.

Finlayson, C.M. and Mitchell, D.S. (1981) Aquatic weeds and impoundment limnology. *In. Burdekin Project Ecological Study.* Australian Government Publishing Service Canberra, 111-126.

Finlayson, C.M. and Mitchell, D.S. (1999) Australian wetlands: The monitoring challenge. *Wetl. Ecol. Manage.*, **7**: 105-112.

Finlayson, C.M. and Rea, N. (1999) Reasons for the loss and degradation of Australian wetlands. *Wetlands Ecol. Manag.*, **7**: 1-11.

Finlayson, C.M. and van der Valk, A.G. (1995) *Classification and Inventory of the World's Wetlands.* Advances in Vegetation Science 16. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Finlayson, C.M. and Von Oertzen, I. (1993) Wetlands of northern Australia. *In. Wetlands of the World I: Inventory, Ecology and Management.* (Eds. D.J. Whigham, D. Dykyova and S. Heijny). Kluwer Academic Publishers, Dordrecht, The Netherlands, 195-243.

Finlayson, C.M., Farrell, T.P. and Griffiths, D.J. (1980) Studies of the hydrobiology of a tropical lake in North-Western Queensland. II. Seasonal changes in thermal and dissolved oxygen characteristics. *Aus. J. Mar. Fresh. Res.*, **31**: 589-596.

Finlayson, C.M., Farrell, T.P. and Griffiths, D.J. (1984a) The hydrobiology of five man-made lakes in North-Western Queensland. *Proc. Royal Soc. Queensland*, **95**: 29-40.

Finlayson, C.M., Ferrell, T.P. and Griffiths, D.J. (1984b) Studies on the hydrobiology of a tropical lake in the North-Western Queensland. III. Growth, chemical composition and potential for harvesting of the aquatic vegetation. *Aus. J. Mar. Fresh. Res.*, **35**: 525-536.

Finlayson, C.M., Hall, R. and Bayliss, B. (1998) Regional review of wetland management issues: Wet-dry tropics of northern Australia. LWRRDC National Wetlands R&D Programm, LWRRDC Occasional Paper, Canberra.

Fisher N.S. and Fabris, J.G. (1982) Complexation of Cu, Zn, and Cd by metabolites excreted from marine diatoms. *Mar. Chem.*, **11**: 245- 255.

Fitzgerald, W.F. and Clarkson, T.W. (1991) Mercury and monomethyl mercury: Present and future concensus. *Environ. Helth. Perspectives*, **96**: 159-166.

Fogg, G.E. (1947) Nitrogen fixation by *Blue-Green Algae*. *Endeavour.*, **6**: 172-175.

Fogg, G.E., Stewart, W.D.P., Fay, P. and Walsby, A.E. (1973) *The Blue-Green Algae*. Academic Press, London and NewYork, 459pp.

Fryer, J. (1987) A new classification on the Branchiopod Crustacea. *Zool. J. Linn. Soc.*, 91: 357-383.

Gaarder, T. and Gran, H.H. (1927) Investigations on the primary production of plankton in the Oso Fjord. *Rapp. Cons. Explor. Mar.*, **144**: 56-60.

Gachter, R., Vollenweider, R.A. and Glooschenko (1974) Seasonal variation of temperature and nutrients in the surface waters of lakes Ontario and Erie. *J. Fish. Res. Bd. Canada*, **31**: 275-290.

Ganapati, P.N. and Murthy, V.S.R. (1955) Preliminary observations on the hydrography and inshore plankton in the Bay of Bengal off Visakhapatnam Coast. *Indian J. Fish.*, **21**: 84-95.

Ganapati, S.V. (1949) The hydrology of three summer pools in the rocky stream bed at Mettur Dam, with special reference to certain abnormal congregation of fishes. *J. Zool. Soc. India*, **1**: 44-48.

Ganapati, S.V. (1956) Hydrobiological investigations of the Hope reservoir and of Thanbaraparni River at Papnasam Tirunalveli, Madras, India. *Indian Geogr. J.*, **31**: 1-2.

Ganapati, S.V. (1960) Ecology of tropical waters. *Proc. ICAR Symp. on Algology*, New Delhi (1958), 200-218.

Ganapati, S.V. and Chacko, P.I. (1951) *Proc. Int. Assoc. Theor. Appl. Limnol.*, **11**: 111-112.

Ganapati, S.V. and Sreenivasan, A. (1970) Energy flow in natural aquatic ecosystems in India. *Arch. Hydrobilol.*, **66**: 458-498.

Ganapati, S.V. and Sreenivasan, A. (1972) Energy flow in aquatic ecosystems in India. Proc. IBP-UNESCO, *Freshwater* (1970). 457-476.

Gannon, J.E. and Stemberger, R.S. (1978) Zooplankton especially *crustaceans* and *rotifers* as indicators of water quality. *Trans. Amer. Micros. Soc.*, **97**(1): 16-35.

Gaur, R.K. (1994) *Temporal and Spatial Distribution of Cyanobacteria in Polluted Water bodies. M.Phil. Dissertation*, AM.U. Aligarh, India, 62pp.

Gaur, R.K. (1998) *Limnology of a Leachate Reservoir Receiving Effluents from a Thermal Power Plant.* Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Gaur, R.K., Khan, A.A., Afaq, M. and Alam, A. (1999) Pollution status of a leachate reservoir receiving effluents from a thermal power plant witn reference to plankton population. *In. Freshwater Ecosystem of India* (Ed. K. Vjaykumar) Daya Publishing House, Delhi, 226-236.

Gaur, R.K., Khan, A.A., Parveen, S. and Untoo, S.A. (2001) Sediment Quality Characteristics of A Leachate Reservoir Receiving Effluents From A Thermal Power plant. *J.Ecophysiol. Occup. Hlth.*, **1**(1&2): 161-178.

George, M.G. (1961) Diurnal variations in two shallow ponds in Delhi, India. *Hydrobiologia*, **18**: 256-273.

George, M.G. (1961a) Observation on the rotifers from shallow ponds in Delhi. *Curr. Sci.*, **30**: 265-269.

George, M.G. (1962) Occurrence of a permanent algal bloom in a fish tank at Delhi with special reference to factors responsible for its production. *Proc. Indian Acad. Sci.*, **56**(6): 362-364.

George, M.G. (1966) Comparative plankton ecology of five fish tanks in Delhi. *Hydrobiologia*, **18**: 265-273.

Gerloff, G.C. and Skoog, F. (1957) Nitrogen as a limiting factor for the growth of *Microcystics aeruginosa* in Southern Wisconsin Lakes. *Ecology*, **38**: 556-561.

Gerloff, G.C., Fitzgebald, G.P. and Skoog, F. (1952) The mineral nutrition of *Microcystis aeruginosa. Amer. J. Bot.*, **39**:26-32.

Ghosh, A. and George, J.P. (1989) Studies on the abiotic factors and zooplankton in a polluted urban reservoir, Hussain Sagar, Hyderabad: Impact on water quality and embryonic development of fishes. *Indian J. Environ. Hlth.*, **37**: 49-59.

Gibbins, C. N., Jeffries, M. J. and Soulsby, C. (2000) Impacts of an inter-basin water transfer: Distribution and abundance of *Micronecta poweri* (*Insecta: Corixidae*) in the River Wear, North-East England. *Aquatic Conserv: Mar.Freshw. Ecostst.*, **10**: 103-115.

Gliwicz, Z.M., Ghilarov, A. and Pijanowska, J. (1981) Food and predation as major factors limiting two natural population of *Daphnia cucullatta* Sars. *Hydrobioogia*, **80**: 205-218.

Goel, P.K., Khatarkar, S.P., Kulkarni, A.Y. and Trivedy, R.K. (1986) Limnological studies of freshwater bodies in south-western Maharashtra wit special reference to their chemistry and phytoplankton. *Poll. Res.*, **5**: 79-84.

Goldman, C.R. (1972) The role of minor nutrients in limiting the productivity of aquatic ecosystems. *Am. Soc. Limno. Oceano.* (Sp. Symp.), **1**: 21-38.

Goldman, J.C. and Gilbert, P.M. (1983) Kinetics of inorganic nitrogen uptake by phytoplankton. *In. Nitrogen in the Marine Environment*, (Eds. E.J. Carpenter and D. Capone), Academic Press, New York, 233-274.

Goldman C.R. and Horne, A.J. (1983) *Limnology*. McGraw-Hill Intl. Book Co., London, 464pp.

Goldman, C.R. and Wetzel, A.J. (1983) A study of primary productivity of clear lakes , lake county California. *Ecology*, **44**(2): 283-294.

Goldman, C.R. (1965) Micronutrient limiting factors and their detection in natural phytoplankton populations. *In*. Primary Productivity in Aquatic Environments. (Ed. C.R. Goldman). Univ. California. *Mem. Inst. Ital. Idrobiol.*, **18**(supplement): 121-136.

Gole, P. (1993) Man-made Wetlands in India: An overview. *In. Wetlands and Waterfowl Conservation in South and West Asia*. Proceedings of International symposium, Karachi, Pakistan 14-20 December, 1991 (Eds. M. Moser and J. Van Vessem) IWRB special Publication No.25, AWB Publication No. 85, IWRB, Slimbridge, United kingdom, and AWB, Kuala Lumpur, Malaysia, 52-53.

Good, R.E., Whigham, W.H. and Simpson, R.L. (1978) *Freshwater Wetlands*. Academic Press, N. York, 378pp.

Gopal, B. (1982a) Ecology and Management of Freshwater wetlands in India. *Proc. Intenational Scientific workshop* (SOPE-UNEP) on Ecosystem Dynamics *In. Freshwater Wetlands And Shallow Waterbodies*, **1**: 127-162.

Gopal, B. (1990) Wetlands mismanagement by keeping people out: Two examples from India.*In. Procd. Int. Conf. on People's Role in Wetland Mang.* Centre for Environmental studies, University of Leiden, Leiden, The Netherlands.

Gopal, B. (1995) *Handbook of Wetland Management*, WWF, India, New Delhi, India, 267pp.

Gopal, B., Hillbrich-Ilkowska, A. and Wetzel, R.G. (1993) *Wetlands and Ecotones: Studies on land-water interactions*. National Institute of Ecology and International Scientific Publications, New Delhi, 301pp.

Gopal, B. Koryavov, P., Kvet, J., Loffler,H., Sverizhev,Y.and Tundisi, J.G. (1990). *Wetlands and Contentinential Shallow waterbodies*. SPB Academic Publishing, The Hague, 373-387.

Gopal, B. and Krishnamurthy, K. (1993) Wetalnds Of South Asia. *In. Wetlands of The World*. (Eds. D.F. Whigham, S. Hejny, and D. Dykyjova). Kluwer Academic Publishers, Dordrecht, The Netherlands, 345-414.

Gopal, B. and Sah, M. (1995) Inventory and classification of Wetlands in India. *Vegetatio*, **118**: 39-48.

Gopal, B., Turner, R., Wetzel, R.G. and Whigham, D.F. (1982). *Wetland Ecology and Management*. National Institute of Ecology and International Scientific Publications, Jaipur, 514pp.

Gopal, R. (1999) Challenges in the water for drinmking and domestic use and remedies. *Indian. J. Environ. Prot.*, **19:** 567-572.

Gordon, D.M., Finlayson, C.M. and McComb, A.J. (1981) Nutrients and phytoplankton in three shallow, freshwater lakes of different trophic status in western Australia. *Aus. J. Mar. Fresh. Res.*, **32**: 541-553.

Gorham, E. (1964) Morphometric control of animal heat budget in temperate lakes. *Limnol. Oceangr.*, **9**: 525-529.

Gosh, A., Hanumantha, R.L. and Banerjee, S.C. (1974) Studies on the hydrobiological conditions of a sewage fed pond with a note on their role in fish culture. *J. Inland Fish. Soc. India*, **6**: 51-61.

Green, J. (1976) Changes in the zooplankton of river Sokoto: The Crustacea. *Proc. Zool. Soc. London*, **138**: 415-453.

Green, J. (1990) Zooplankton association in Zimbabwe. *J. Zool. Lond.*, **220-222**: 259-283.

Green. J. (1990a) Changes in zooplankton of lakes Mutanda Bunyonyi and Mulehe, Uganda. *Fresh Wat. Biol.*, **6**: 433-436.

Greenson, P.E., Clark, J.R. and Clark, J.E. (1979) Wetlands, values and functions: The status of our understanding. *Proc. National Symp. on Wetlands.*, American Water Resources Association, Minneapolis , Minnesota, 674pp.

Greg, S., Carol, A.M. and Larry, R. (1999) Physiological characterization of *Pseudomonas aeruginosa* during exotoxia synthesis: Gultamate iron limitation and aconitase activity. *J. Bacteriol.*, **181**: 1070-1078.

Griffiths, B.M. (1923) The phytoplankton of freshwater bodies and factors determining its occurrence and composition. *J. Ecol.*, **11**: 184-213.

Gulatti, R.D. (1978) The ecology of common planktonic crustacea of fresh water in the Netherlands. *Hydrobiologia*, **59**: 101-112.

Gunale, V. R. (1991) Algal communities as indicators of pollution. *J. Environ. Biol.*, **12**(Special number): 223-232.

Gupta, A.K. and Mehrotra, R.S. (1991) Ecological studies on water molds of Kurukshetra. *In. Current Trends in Limnology*. (Ed. N.K. Shastree). Narendra Publishing House, Delhi, India, **1**: 47-64.

Gupta, O.P. (1973) *Aquatic Weed Control for Efficient Water Use*. Rajasthan College of Agriculture, Univrsity of Udaipur, India, 97pp.

Hails, A.J. (1996/1997) Wetlands, biodiversity and the Ramsar Convention: The role of the convention on wetlands in the conservation and wise use of biodiversity. (Ed.). Ramsar Convention Bureau, Ministry of Environment and Forests, India.

Hairston Jr., N.G. and Dillon, T.A. (1990) Fluctuating selection and response in a population of freshwater copepods. *Evolution*, **44**: 1796-1805.

Halbach, U. (1984) Population dynamics of rotifers and its consequences for ecotoxicology. *Hydrobiologia*, **109**: 79-96.

Halbach, U. (1970b) Die Ursachen der temporalvariation von *Brachionus calyciflorus* Pllas (Rotatoria). *Oekologia.*, **4**: 265-318.

Hall, D.J., Threlkeld, S.T., Burns, C.W. and Crowlery, P.H. (1976) The size-efficiency hypothesis and the size structure of zooplankton communities. *Ann. Rev. Ecol. Syst.*, **7**: 177-208.

Hanazato, T. and Yasuno, M. (1989) Zooplankton community structure driven by vertebrate and invertebrate predators. *Oekologia*, **81**: 450-458.

Handa, D.P., Hazra, C.R. and Sood, R.M. (1987) Weather analysis and climatological characterization of Banda, U.P. *Indian J. Forestry*, **10**(2): 119-126.

Han Sang-Hoon (1995) Wetland ecosystems and its importance. *Nature Conservation*, **91**: 42-50.

Haque, N. (1991) *Studies on Hydrobiology of Some Polluted Ponds of Aligarh Region*. Ph.D. Thesis. Aligarh Muslim University, Aligarh, India.

Haque, N., Khan, A.A. Fatima, M. and Barbhuyan, S.I. (1988) Impact of some ecological parameters on rotifer population in a tropical perennial pond. *Environment & Ecology*, **6**(4): 998-1001.

Harris, R.C. (1967) Silica and chloride in interstitial waters of river and lake sediments. *Limnol. Oceanogr.*, **12**(1): 8-12.

Hasler, A.D. (1947) Eutrophication of lakes by domestic drainage. *Ecology*, **28**: 285-295.

Hazarika, A.K. and Dutta, A. (1988) Limnological studies of two fresh water ponds of Guwahati, Assam. *Environment & Ecology*, **12**: 26-29.

Hazelwood, D.H., and Parker, R.A. (1961) Population dynamics of some fresh water Zooplankton. *Ecology*, **42**: 266-274.

Hebert, P.D.N. and Taylor, D. (1997) The future of Cladoceran genetics: Methodologies and targets. *Hydrobiologia*, **360**: 295-299.

Hecky, R.E. and Kilham, P. (1988) Nutrient limitations of phytoplankton in freshwater and marine environments: A review of recent evidences on the effects of enrichment. *Limnol. Oceanogr.*, **33**: 796-822.

Hedge, G.R. (1985) Comparison of phytoplankton biomass in four water bodies of Dharward, Karnataka, India. *Proc. Indian Acad. Sci.* (Sec. B), **94**(4-6): 583-587.

Hemesath, L.M. and Dinsmore, J.J. (1993) Factors affecting bird colonization of restored wetlands. *Praire Naturalist*, **25**: 1-11.

Henriksen, A. and Brakke, D.F. (1988) Increasing contributions of nitrogen to the acidity of surface waters in Norway. *Water Air Soil Poll.*, **42**: 183-201.

Herzig, A. (1987) The analysis of planktonic rotifer populations: A plea for long-term investigations. *Hydrobiologia*, **147**: 163-180.

Heyligers, P.C., Kalma, J.D., and Loffler, E. (1985) Aspects of Australian Wetlands. Division of Water and Land Resources, Paper No. 44, CSIRO, Australia.

Hillbricht-Illkowska, A., Ejsmont Karabin, J. and Weglenka, T. (1988) Long term changes in the composition, productivity and trophic efficiency in the zooplankton community of heated lakes near Konin (Poland). *Ekol. Pol.*, **36**(1-2): 115-144.

Hindall, S.M. (1975) Measurement and predation of sediment yield in Wisconsin Streams. *U.S. Geo. Survey Water Res. Investig.*, **54/75**: 27pp.

Hocking, P.J., Finlayson, C.M. and Chick, A.J. (1983) The biology of Australian weeds: 12. *Phragmites australis* (Cav.). *J. Aust. Inst. Agri. Sc.*, **50**: 123-131.

Hodgets, J. (1921) A study of some of the factors controlling the periodicity of freshwater algae in nature. *New Phytol.*, **20**: 150pp.

Hofmann, W. (1977) The influence of abiotic environmental factors on population dynamics in planktonic rotifers. *Arch. Hydrobiol.*, **8**: 77-83.

Hofmann, W. (1980) On morphological variation in *Keratella cochlearis* populations from Holstein Lakes (North Germany). *Hydrobiologia*, **73**: 255-258.

Hofmann, W. (1983) Interactions between *Asplanchn*a and *Keratella cochlearis* in the Pluss-see (North Germany). *Hydrobiol*ogia, **104**: 363-365.

Hofmann, W. (1987) Population dynamics of hypolimnetic rotifers in the Pluss-see, North Germany. *Hydrobiologia*, **147**: 197-201.

Hollis, G.E. (1992) The causes of wetland loss and degreadation in the Mediterrianean. *In. Managing Mediterranean Wetlands and their Birds* (Eds. C.M. Finlayson, G.E. Hollis and T.D. Davis). IWRB Special Publication, Slimbrige, UK, **20**: 83-92.

Hollis, G.E. and Finlayson, C.M. (1996) Ecological Changes in Mediterrianean Wetlands. *In. Methodological Guide to Monitoring Mediterranean Wetlands.* (Ed. P. Tomas-Vines) Medwet Publication, Wetland International, Slimbridge, UK and ICN, Lisboa, Portugal, 5-24.

Hollis, G.E., Patterson, J.H., Papayannis, T. and Finlayson, C.M. (1992) Sustaining Wetlands: Policies, programmes and partnerships *In. Managing Mediterranean Wetlands and their Birds* (Eds. C.M. Finlayson, G.E. Hollis and T.D. Davis). IWRB Special Publication, Slimbrige, UK, **20**: 281-285.

Hosetti, B.B., Patil, H.S., Rodgi, S.S. and Gaddas, S.M. (1985) Effect of detention period on the bio-chemical activities of sewage stablization pond: A laboratory study. *J. Environ. Biol.*, **6**(1): 1-6.

Hosetti, B.B. (2002) *Wetlands Conservation and Management.* (Ed. B.B. Hosetti). Pointer Publishers, Jaipur, India, 317pp.

Hosmani, S. (2002) Ecological diversity of algae in freshwaters. *In. Wetlands Conservation and Management.* (Ed. B.B. Hosetti). Pointer Publisher, Jaipur, India, 65-84.

Howland, Z.J. (1931) A four year investigation of the Hertfordshire Pond. *New Phykos.*, **30**: 221-265.

Hulbert, E.M., Ryther, J.H. and Gullard, R.R.L. (1960) The phytoplankIton of the Sargasso Sea of Bermuda. *J. Cons. Perm. Int. Explor Mer.*, **25**: 115-128.

Husainy, S.U. (1967) Studies on the limnology and primary production of a tropical lake. *Hydrobiologia*, **30**: 335-352.

Hussain, Z. (1993) The management of Sundarbans Forest, Bangladesh. *In. Wetlands and Waterfowl Conservation in South and West Asia,* Proceedings of International Symposium, Karachi, Pakistan 14-20 December, 1991 (Eds. M.Moser and Jvan Vessem). IWRB Special Publication No. 25, AWB Publication No. 85, IWRB, Slimbridge, UK and AWB, Kuala Lumpur, Malayasia, 132-135.

Hutchinson, G.E. (1957) *A Treatise on Limnology: Geography, Physics and Chemistry.* Vol. 1. John Wiley & Sons Inc., New York, USA.

Hutchinson, G.E. (1967) *A Treatise on Limnology: An Introduction to Lake Biology and the Limnoplankton.* Vol. 2. John Wiley & Sons Inc., New York, 115pp.

Hutchinson, G.E. (1975). *A Treatise on Limnology. Chemistry of Lakes.* Vol. 1. Part II. John Wiley & Sons Inc., New York.

Hutchinson, G.E. (1975a) *A Treatise on Limnology: Limnological Botany.* Vol. 3. John Wiley & Sons Inc., New York.

Hynes, H.B.N. (1963) *The Biology of Polluted Waters.* Liverpool University Press, Liverpool, UK, 202pp.

Hynes, H.B.N. (1964) The use of biology ion the study of water pollution. *Chem. Ind.*, **2**: 435-436.

Hynes, H.B.N. and Greib, B.J. (1970) Movement of phosphate and other ions from and through lake muds. *J. Fish. Res. Bd. Canada*, **27**: 653-668.

Idris, B.A.G. (1983) Freshwater Zooplankton of Malayasia (Crustacea : Cladocera). Penerbit Unive, Pertanian, Malayasia,153pp.

Imber, B.E., Robinson, M.G., Ortega, A.M. and Burton, J.D. (1985). Complexation of Zn by exudates from *Skeltoma costatum* growth in culture. *Mar. Chem.*, **16**: 131-139.

Ingram, B.A., Hawking, J.H. and Shiel, J. (1997) Aquatic life in freshwater ponds: A guide to the identification and ecology of life in aquaculture ponds and farm in South Eastern Australia. Identification guide no. 9. Co-operative Research Center for Freshwater Ecology, Albury, NSW, Australia, 1-105.

IUCN (International Union for Conservation of Natural Resources) (1971) The Ramsar Convention. The Final Act Of the International Conference on the conservation of Wetlands and Waterfowl. *IUCN Bulletin 2, Special suppliment*, 1-4.

IWRB. Japan Committie (1989) *Japanese Wetland Inventory of International Importance, Espacially as Habitat for Waterbirds.* IWRB Japan Committee, Tokyo, Japan.

Jackson, S.T. and Charles, D.F. (1988) Aquatic macrophytes in Adirondack (New York) Lakes: Patterns of species composition in relation to environment. *Can. J. Bot.*, **66**: 1449-1460.

Jacobs, S.W.L. and Brock, M.A. (1993) Wetlands of southern (temperate) Australia. *In. Wetlands of the World I: Inventory, Ecology and Management.* (Eds. D.J. Whigham, D. Dykyova and S. Heijny). Kluwer Academic Publishers, Dordrecht, The Netherlands, 244-304.

Jak, R.G. (1997) *Toxicant Induced Changes in Zooplankton Communities and Consequences for Phytoplankton Development.* Doctoral Thesis. Universiteit in Amsterdam, Netherlands.

Jak, R.G., Maas, J.L., Scholten, Th.M.C. (1996) Evaluation of laboratory derived toxic concentrations of a mixture of metals by testing fresh water plankton communities in enclosures. *Water Res.*, **30**:1215-1227.

Jana, B.B. (1973) Seasonal periodicity of plankton in a freshwater pond in West Bengal, India. *Int. Rev. Ges. Hydrobiologia.*, **58**: 127-143.

Jana, B.B. (1974) Rhythm of plankton in tropical freshwater ponds in Shantiniketan, India. *Ecol. Pol.*, **22**(2): 284-294.

Jana, B.B. and Sarkasr, H.L. (1971) The Limnology of Swetganga: A thermal spring of Bakreswar, W.B., India. *Hydrobiologia*, **37**: 33-47.

Jaworski, E., Raphael, C.N., Mansfield, P.J. and Williamson, B.B. (1979) Impact of great lakes water levels on coastal wetlands. Department of Geography-Geology, Eastern Michigan University, Ypsilanti, Michigan, U.S.A.

Jenkins, D.G. (1995) Dispersal-limited zooplankton distribution and community composition in new ponds. *Hydrobiologia*, **313/314**: 15-20.

Jerath, N. (1992) The environs and problems of Harike wetlands: some strategies for conservation. *In. Wetland of India.* (Ed. K.J.Chatrath). Asish Publishing House, New Delhi, 103-124.

Jerlov, N.G. (1951) Optical studies of ocean waters. *Rep. Swedish Deep-sea Exped.* 1947-1948, **3**(1): 3-59.

Jeye, Y. and Fernando, C.H. (1986) Identification of Nigerian zooplankton. *Publ. Kainji. Res. Inst.*, 42pp.

Jhingran, V.G. (1975) *Fish and Fisheries of India.* Hindustan Publishing Corporation, India, 727pp.

Jhingran, V.G. (1991) *Fish and Fisheries of India.* Hindustan Publishing Crop. India, Delhi, 954pp.

Jochimsen, E.M., Carmichael, W.W., Cardo, D.M.J.AN., Cookson, S.T., Holmes, C.E.M., Antunes, M.B., MeloFilho, D.A., Lyra, T.M., Barreto, V.S.T., Azevedo, S.M.F.O. and Jarvis, W.R. (1998) Liver failure and death after exposure to *Microcystis* at a hemodialysis center in Brazil. *New England J. Medicine*, **338**(13): 873-878.

Johnson, R.G. (1965) Temperature variation in the infaunal environment of a sand flat. *Limnol. Oceangr.*, **10**: 114-120.

Jonauskas, P. (1996) Proceedings wetlands workshop: Making multiple landuse work. Department of Lands, Planning and Environment, Nothern Territory *Government Publishing Service, Palmerston.*

Jones, H. R., Lack, T.J. and Jones, C.S. (1979) Population dynamics and production of *Daphnia hyaline* var *locustris* in Farmoor: A shallow eutrophic reservoir. *J. Plankton Res.*, **1**: 45-65.

Juday, C. Birge, E.A. and Meloche, V.W. (1938) Mineral content of the lake waters of North-Eastern Wisconsin. *Trans. Wis. Acad. Sci. Arts. Letts.*, **31**: 225-276.

Jupp, B.P. and Spence, D.H.N. (1977) Limitations of macrophytes in a eutrophic lake, Loch Leven. I. Effects of Phytoplankton. *J. Ecol.*, **65**:175-186.

Jyoti, N.K. and Sehgal, H. (1979) Ecology of rotifers of Surinsar: A sub-tropical freshwater lake in Jammu, J. & K., India. *Hydrobiologia*, **65**(1): 23-32.

Kamat, N.D. (1981) Diatoms and diatom populations indicating water quality and pollution. Paper presented at W.H.O. workshop on Biological Indicators and Indices of Environmental Pollution 1981. *Cent. Bd. Prev. Cont. Water Poll.* Osm. Univ., Hyderabad, India.

Kanabur, V.V. (1990) Ecological influence on nitrogen metabolism in sewage near Sharanabasa Veshwar Tank at Gulbarga. *Trends in Ecotoxicology*, 117-121.

Kant, S. and Raina, A.K. (1990) Limnological studies of two ponds in Jammu. II. Physico-chemical parameters. *J. Environ. Biol.*, **11**: 137-144.

Kar, D. (1984) *Limnology And Fisheries of Lake Sone In The Cachar District of Assam India.* Ph.D Thesis. Guwahiti University, Assam, 201pp.

Karr, R.L. (1989) Effect of flooding on green tree reservoirs. *In.* Interim Technical Report FY 1988-1989. Water Resources Research Institute, Mississippi State University, Mississippi, U.S.A., 14-29.

Karr, J.R. (1991) Biological integrity: A long neglected aspect of water resource management. *Ecological Applications*, **1**: 66-84.

Kaul, V. (1977) Limnological survey of Kashmir Lakes with reference to trophic status and conservation. *Int. J. Ecol. Environ. Sc.*, **3**: 29-44.

Kaur, H., Bath, K.S., Mandar, G. and Jerath, N. (2000) Physico-chemical status of Kanjli wetland, Punjab, India. *J. Environ. Poll.*, **7**: 59-62.

Kaushik, S. and Saksena, D.N. (1999). Physico-chemical limnology of certain waterbodies of central India. *In. Freshwater Ecosystem of India.* (Ed. K Vijaykumar). Daya Publishing House, New Delhi, 1-58.

Kaushik, S. and Sharma, N. (1994) Physico-chemical characteristics and Zooplankton population of a perennial tank, Matsya Sarovar, Gwalior. *Environment & Ecology*, **2**: 429-434.

Kaushik, S., Sharma, S. and Saksena, D.N. (1990) Abundance of insects in relation to physico-chemical characteristics of pond water at Gwalior, M.P. *Proc. Nat. Acad. Sci.*, India.

Kaushik, S., Sharma, S. and Saxena, M.N. (1989) Aquatic insect population in relation to physico-chemical characteristic of Chandanpura Pond, Gwalior, M.P. *In. Environmental Risk Assessment* (Eds. V.N. Sahai, P.B. Deshmukh, T.A. Mathai and K.S. Pillai). *Academy of Environmental Biology*, India, 243-254.

Kaushik, S., Sharma, S. and Saksena, D.N. (1991a) Ecological studies of certain polluted lentic waters of Gwalior region with reference to aquatic insect communities. *In. Current Trends in Limnology.* I. (Ed. N.K. Shastree). Narendra Publishing House, N. Delhi, 185-200.

Kaushik, S., Agarker, M.S. and Saksena, D.N. (1991b) Water quality and periodicity of phytoplanktonic algae in Chambal Tank Gwalior, M.P. *Bionature*, **4**: 87-94.

Keddy, P. (1986) Great lakes vegetation dynamics: The role of fluctuating water levels and buried seeds. *J. Great Lakes Res.*, **12**(1): 25-36.

Keddy, P. (1991) Biological monitoring and ecological prediction: From nature reserve management to national state of environment indicators. *In. Monitoring for Conservation and Ecology.* (Eds. E. Weiher and P.A. Keddy). Cambridge University Press, Cambridge, U.K.

Keddy, P. (1999) Wetland restoration: The potential for assembly rules in the service of conservation. *Wetlands*, **19**(4): 716-732.

Keddy, P. (2000) *Wetland Ecology: Principles Conservation.* Cambridge University Press, Cambridge.

Keddy, P. and Fraser, L.H. (2000) Four general principles for the management and conservation of wetlands in large lakes: The role of water levels, nutrients, competitive hierarchies and centrifugal organization. *Lakes and reservoirs: Research and management*, **5**: 177-185.

Keddy, P.A. and Wisheu, I.C. (1989) Ecology, biogeography and conservation of coastal plain plants: Some general principles from the study of Nova Scotian wetlands. *Rhodora*, **91**: 72-94.

Keddy, P.A., Lee, H.T. and Wisheu, I.C. (1993) Choosing indiactors of ecosystem integrity: wetlands as a model system. *In. Ecological Integrity and Management of Ecosystems.* (Eds. S.Woodley, J.Kay, and G. Francis) St. Lucie Press, Delray Beach, FL, USA, 61-79.

Keller, W. and Yan, N.D. (1991) Recovery of crustacean zooplankton species richness in Sudbury area lakes following water quality improvements. *Can. J. Fish. Aquat. Sci.*, 48: 1635-1644.

Kemp, W.M., Twilley, R.R., Stevenson, J.C., Boynton, W.R. and Means, J.C. (1983). The decline of submerged vascular plants in upper Chesapeake Bay: Summary of results concerning possible causes. *Mar. Tech. Soc. J.*, **17**: 78-79.

Kemp, P.H. (1971) Chemistry of natural waters. VI. Classification of waters. *Water Res.*, **5**: 945-956.

Kemp, M.J. and Doods, W.K. (2001) Spatial and Temporal patterns of nitrogen concentrations in pristine and agriculturally influenced prairie streams. *Biogeochemistry*, **53**: 125-141.

Kerfoot, W.C. (1987) Translocation experiments: *Bosmina* responses to copepod predation. *Ecology*, **68**: 596-610.

Khan, A.A. (1969) *Studies on The Limnology and Primary Productivity of Aligarh Freshwaters*. Ph.D. Thesis. A.M.U. Aligarh, India, 166pp.

Khan, A.A. and Alam, A. (1999) Cyclomorphosis, the morphological responses in Cladocera (Waterfleas) to certain environmental factors: A review. *In. Freshwater Ecosystem of India.* (Ed. K. Vijaykumar). Daya Publishing House, N. Delhi, 193-207.

Khan, A.A., Alam, A. and Gaur, R.K. (1999) A comprehensive study of water quality parameters in the river Ganga between Narora and Kannauj: Primary production. *In. Freshwater Ecosystem of India* (Ed. K. Vijaykumar) Daya Publishing House, N. Delhi, 287-294.

Khan, A.A. and Siddiqui, A.Q. (1971) Primary production in a tropical fish pond at Aligarh, India. *Hydrobiologia*, **37**: 447-456.

Khan, A.A. and Siddiqui, A.Q. (1974) Seasonal changes in limnology of a perennial fish pond at Aligarh. *Indian J. Fish.*, **21**: 463-478.

Khan, A.A., Siddiqui, A.Q., Ali, M. and Hameed, T. (1978) Physico-chemical and biological characteristics of a pond, Chautal. *J. Zool. Res.* **2**(1): 1-13.

Khan, A.A., Untoo, S.A. and Parveen, S. (2002) Limnology of a reservoir receiving effluents from a thermal power plant. *In. Ecology of Polluted Waters*. (Ed. A. Kumar), A.P.H. Publishing Corporatiopn Delhi, 1109-1117.

Khan, I.A. and Khan, A.A. (1985) Physico-chemical conditions in Seikha Jheel at Aligarh. *Environment and Ecology*, **3**(2): 269-174.

Khan, I.A., Khan A.A. and Haque, N. (1988) Primary production in Seikha Jheel at Aligarh. *Environment and Ecology*, **6**(4): 858-862.

Khan, J.A. and Qayyum, A. (1966a) On the occurrence of carbon dioxide in a tropical pond *Labdev*, **4**(1): 63-65.

Khan, J.A. and Qayyum, A. (1966b) On the ionic composition of five tropical fish ponds of Aligarh, U.P., India. *Hydrobiologia*, **28**(2): 195-201.

Kanna, K (1991) *Fundamentals of Environmental Pollution*. S. Chand & Co., Ltd, New Delhi, India.

Khan, M.A. and Rao, I.S. (1981) Zooplankton in the evaluation of pollution. *Cent. Bd. Prev. Cont. Poll. Osm. Univ. Hyderabad*, India, 121-133.

Khan, M.A. and Zutshi, D.P. (1979) C^{14} Planktonic primary production measurements of lower Siwalik lakes. *Geobios*, **6**: 23-25.

Khan, M.A. and Zutshi, D.P. (1980) Contribution to high altitude limnology of Himalayan system. I. Limnology and primary productivity of the plankton community of Nilnog lake, Kashmir. *Hydrobiologia*, **75**: 103-112.

Khan, M.A., Singh, H.P., Dwivedi, R.K., Singh, D.N. and Tyagi, R.K. (1996) Ecology and fish yield from Bangla Reservior: A small impoundment in Ganga basin. *J. Inland Fish. Soc. India*, **28**(2): 91-100.

Khan, R.A., and Sinha, C. (1999) Biodiversity of freshwater zooplankton in Southern West Bengal. (Abs.). International Conference on Tropical Aquatic Ecosystems. Health, Management, and Conservation. Nainital, India, 65pp.

Khatavakar, S.D., Kulkarni, A.Y. and Goel, P.K. (1995) Observations on the diurnal cycles of phytoplankton and some nutrients during summer in the surface waters of shallow mesotrophic lake. *Geobios*, **16**: 210-214.

Kingsford, R.T. (1998) Managing the waters of the broader rivers in Australia: Irrigation, Government and the Wetland environment. *Wetl. Ecol. Manage.*, **7**: 25-35.

Kirk, J.T.O. (1979) Spectral distribution of photosynthetically active radiation in Some South-eastern Australian waters. *Aust. J. Mar. Fresh. Res.*, **30**: 81-91.

Kirk, J.T.O. (1986) *Light and Photosynthesis in Aquatic Ecosystems.* Cambridge University Press, New York, 401pp.

Klapper, H. (1992) *Eutrophierung und Gewasserschutz.* Gustav Fischer Verlag, Jena, Stuttgart.

Köhler, J. (1992) Influence of turbulent mixing on growth and primary production of *Microcystis aeruginosa* in the hypertrophic Bautzen reservoir. *Arch. Hydrobiol.*, **123**: 413-429.

Korovchinsky, N.M. (1992) Sididae and Holopedidae. *In. Guides to the Identification of the Microinvertebrates of the Contitential Waters of the World.* Vol. 3. SPB Academic Publishers, The Hague, 82pp.

Korovchinsky, N.M. (1996) How many species of Cladocera are there? *Hydrobiologia*, **321**: 191-204.

Korovchinsky, N.M. (2000) Trends in Cladocera and Copepoda taxonomy. *Arthropoda Selecta*, **9**(3): 153-158.

Koste, W. (1978) *Rotatoria.* Die Rädertier Mittleuropas, begründet von Max Voigt. Überordnung Monogonton. Gebrüder Borntraeger, Berlin, Stuttgart. Text. (1-675) u II. Tafelbd.T, 1-234.

Kulshreshtha, S.K., Adhohia, U.N., Khan, A.A., Bhatnagar, A. and Saxena, M. (1987) Assessment of water quality of Kshipra river by algal analysis. *Proceedings of 8th Annual Session and Symposium of AEB on "Environmental Pollution and Pesticide Toxicology"*, held at University of Jammu, India, 243-254.

Kumar, A. (1995) Some limnological aspects of the freshwater tropical wetland of Santhal Pargana, Bihar, India. *J. Environ. Poll.*, **2**(3): 137-141.

Kumar, A. (1997) Biomonitoring of pollution by aquatic insect community and micro-orgnisms. *In. Freshwater Ecosystems. Ecotechnology Of Pollution Control And Environment Management.* (Eds. R.K. Trivedy and A. Kumar), Environmedia, Karad, (In Press).

Kumar, A. (2002a) *Ecology of Polluted Waters.* Vol. 1 and 2. A.P.H Publishing Corporation, N. Delhi, 1233pp.

Kumar, A. (2002b) Ecology and Ethology of Aquatic Biota. Vol. 1 and 2. Daya Publishing House, Delhi, 405 pp.

Kumar, S. and Dutta, S.P.S. (1994) Population dynamics of Cladocera in a subtropical pond, Jammu. *Indian J. Environ. Hlth.*, **36**(1): 19-23.

Kumari, P. and Kumar, A. (2002) Periodicity and biomass potentials of macrophytes in polluted aquatic environment of Jharkhand. *In. Ecology of Polluted Waters, II.* A.P.H. publishing Corp., N. Delhi.759-772.

Kutikova, L.A. (1970) Rotifer fauna of USSR. Subclass Eurotatoria (in Russian). *Fauna USSR Akad. Nauk. Leningrad*, **104**: 1-744.

Kutikova, L.A. (1983) Parallelism in the evolution of rotifers. *Hydrobiologia*, **104**: 3-7.

Lafond, E.C. (1962) Marine meteorology and its relation to organic production in South-East Asian water. *J. Mar. Biol. Ass. India*, **4**(1): 19pp.

Lampert, W. (1982) Further studies on the inhibitory effect of the toxic blue-green algae, *Microcystis aeruginosa* on the filtering rate of zooplankton. *Arch. Hydrobiol.*, **95**: 207-220.

Lampert, W. (1993) Ultimate causes of diel vertical migration of zooplankton: New evidence for the predation-avoidance hypothesis. *Arch Hydrobiol. Beih. Ergebn Limnol.*, **39**: 79-88.

Lampert, W. (1997) Zooplankton research: The contribution of limnology to general ecological paradigms. *Aquatic Ecol.*, **31**: 19-27.

Larson, J.S. (1982) Wetlands Value and Assessment. *In. Wetland Ecology and Management.* (Eds. R.E. Turnner, R.G. Wetzel and D.F. Whigham). National Institute of Ecology and International Scientific Publications, Jaipur, 417-424.

Larson, D.W. (1972) Temperature transparency and phytoplankton productivity in crater lake Oregon. *Limnol. Oceanogr.* **17**: 410-417.

Larson, J.S., Mueller, A.J. and MacConnell, W.P. (1980) A model of natural and man-induced changes in open freshwater wetlands of the Massachusetts coastal plain. *J. Appl. Ecol.*, **17**: 667-673.

Leck, M.A. (1989) Wetland seed banks. *In. Ecology of Soil seed banks.* (Eds. M.A. Leck, V.T. Parker and R.L. Simpson). Academic Press, San Diego, CA, USA.

Levine, D.A. and D.E. Willard (1990) Regional analysis of fringe wetlands in the Midwest: Creation and restoration. *In. Wetland Creation and Restoration: The Status of the Science.* (Eds. J.A. Kusler and M.E. Kentula). Island Press, Washington, DC, USA.

Lefever, M., Jakob, H. and Nisbet, M. (1952) Autoet hetero-antagonisme chez les algues d'eaudouce. *Ann. Stat. Cent. Hydrobiol. Appl.*, **4**: 5-197.

Lehman, J. T. (1988) Ecological principles affecting community structure and secoundary production by zooplankton in marine and freshwater environments. *Limnol. Oceanogr.*, **33**: 931-945.

Lewis, J.C. (1954) Silicon metabolism in diatoms. I. Evidence for the role of reduced sulphur compounds in silicon utilization. *J. Gen. Physiol.*, **37**: 589-599.

Lewis Jr., W.M. (1974) Primary production in the plankton community of a tropical Lake. *Ecol. Monogrph*, **44**: 377-409.

Likens, G.E. and Bormann, F.H. (1972) Nutrient cycling in ecosystems. *In. Ecosystem, Structure and Function*. (Ed. J.A. Weins). Corvallis, Oregon State University Press, 25-67.

Lilljeborg, W. (1900) Cladocera sueciae. *Nova Acta Reg. Soc. Sci.* Uppsala Ser. III.

Lim, R.P. and Frenando, C.H. (1978) A review of Malaysian freshwater Copepoda with notes on new records and little known species. *Hydrobiologia*, **128**: 71-98.

Lin, C.K. (1972) Phytoplankton succession in a Eutrophic Lake with special reference to blue-green algal blooms. *Hydrobiologia*, **39**(3): 321-334.

Loeb, S.L. (1994) An ecological context for biological monitoring. *In. Biological Monitoring of Aquatic Systems*. (Eds. S.L. Loeb and A. Spaecie). Lewis Publishers, New York, 3-7.

Lohammer, G. (1938) Wsserchemie and honere vegetation schwedischer seen. *Symboles Botaniceae upsaliensis*, **3**: 252pp.

Lorenzen, M.W. (1980) Use of chlorophyll-Secchi disc relationships. *Limnol. Oceanogr.*, **25**(2): 372-372.

Losordo, T.M. and Piedrahita, R.H. (1991) Modelling temperature variation and thermal stratification in shallow aquaculture ponds. *Ecological Modelling*, **54**(3): 189-226.

Lowell, R.B. and Culp, J.M. (1999) Cumulative effects of multiple effluent and low dissolved oxygen stressors on mayflies at cold temperature. *Can. J. Fish. Aqut. Sci.*, **56**: 1624-1630.

Lu, J. (1990) Wetlands in China: Update from *A Directory of Asian Wetlands*. Institute of Estuarine and Coastal resources, East China Normal University, Shanghai, China.

Lu, J. (1995) Ecological significance and classification of Chinese wetlands. *In. Classification and Inventory of World's Wetlands*. (Eds. C.M. Finlayson and A.G. van der Valk) reprints from *Vegetatio*, **118**: 49-56.

Lund, E.M. (1965) Studies on the periodicity of the algae in the Beauchief ponds, Sheffield. *J. Ecol.*, **26**: 257-274.

Lund, J.W.G. (1965) The ecology of freshwater plankton. *Bio. Rev.*, **40**(2): 231-293.

Lunte, C.C. and Luecke, C. (1990) Trophic intractions of *Leptodora* in lake Mendotae, *Limnol. Oceanogr.*, **35**: 1091-1100.

Maara, J. Chamberlin, W.S. and Kundson, C. (1993). Proprortionality between *in-situ* carbon assimilation and bio-optical measures of primacy production in the Gulf of Maine in summer. *Limnol. Oceanogr.*, **38**: 232-238.

Maemets, A. (1983) Rotifers as indicators of lake types in Estonia. *Hydrobiologia*, **104**: 357-361.

Maguire Jr., B. (1963) The passive dispersal of small aquatic organisms and their colonisation of isolated bodies of water. *Ecol. Monograph*, **33**: 161-185.

Mahajan, C. L. (1981) Zooplankton as indicators for assessment of water pollution. Paper presented at WHO workshop on biological indicators and indices of environmental pollution-1981. *Cent. Bd. Prev. Cont. Poll., Osm. Univ.*, Hyderabad, India, 35-148.

Mahajan, C. L. and Singh, J.J. (1973) Water pollution in relation to the biology of fishes. I. A Comparative study of the toxicity of synthetical detergents to fresh water organisms. *Proc. Symp. Environ. Poll., CPHERI*, Nagpur, India, 9-17.

Mairs, D.F. (1966) A total alkalinity atlas for marine lake waters. *Limnol. Oceanogr.*, **11**: 68-72.

Malone, T.C., Conley, D.J., Fisher, T.R., Glibert, P.M., Harding Jr., L.W. and Sellner, K.G. (1996) Scales of nutrient limited phytoplankton productivity in Chesapeake Bay. *Estuaries*, **19**: 371-385.

Malone, T.C., Kemp, W.M., Ducklow, H.W., Boynton, W.R., Tuttle, J.H. and Jones, R.B. (1986) Lateral variation in the production and fate of phytoplankton in a partially stratified estuary. *Mar. Ecol. Prog. Ser.*, **32**: 149-160.

Maltby, E. (1986) *Waterlogged Wealth: Why Waste The Worlds Wet Places?* Earthscan, London WC1H ODD, U.K., 200pp.

Mamaril, A.C. and Fernando, C.H. (1978) Freshwater zooplankton of the Philippines (*Rotifera, Cladocera* and *Copepoda*). Univ. Philipp. *Nat. Appl. Sci. Bull.* **30**:109-221.

Marimuthu, R. and Krishnamurthy, V. (1985) Diurnal studies of phytoplankton ecology in two small tropical pools. *Proc. Nat. Symp. Pure & Appl. Limnol.* (Ed. A.D. Adoni). *Bull. Bot. Soc.*, Sagar, India, **32**: 240-243.

Marmorek, D.R. and Korman, J. (1993) The use of zooplankton in a biomonitoring program to detect lake acidification and recovery. *Water, Air and soil Pollut.* **69**: 223-241.

Martin, J. and Cash-Clark, C.E. (1995) The external morphology of the onychopod cladoceran genus *Bathytrephes* (Crustacea, Branchiopoda, Onychopoda, Cercopagidae), with notes on the morphology and phylogeny of the order Onychopoda. *Zool. Scripta*, **24**: 61-90.

Mathew, P.M. (1975) Limnology and productivity of Govindgarh Lake, Rewa, M.P. *J. Inland Fish. Soc. India*, **32**: 240-243.

Matthews, G.V.T. (1993) *The Ramsar Convention on Wetlands: Its History and Development*. Ramsar Convention Bureau, Gland, Switzerland.

Maucha, R. (1932) Hydrochemische Methoden in der Limnologie. *Die Binnengewesser*, **12**: 173pp.

Mayer, P.M. and Galatowitsch, S.M. (1999) Diatom communities as ecological indicator of recovery in restored prairie wetlands. *Wetlands* **19**(4): 765-774.

McCauley, E. and Kalff, J. (1981) Empirical relationship between phytoplankton and zooplankton biomass in lakes. *Can. J. Fish Aquat. Sci.*, **38**: 458-463.

McComb, A.J. and Lake, P.S. (1988) *The Conservation of Australian Wetlands*. Surrey Beatty and Sons Pvt. Ltd., Sydney.

McComb, J.A. and McComb, A.J. (1967) A preliminary account of the vegetation of Loch McNess: A swamp and fen formation in Western Australia. *J. Royal Soc. Western Aus.*, **50**: 105-112.

McCombie, A.M. (1953) Factors influencing the growth of phytoplankton. *J. Fish. Res. Bd. Canada.*, **20**: 685-727.

McCormick, J. (1978) Ecology and the regulation of freshwater wetlands. *In. Freshwater Wetlands: Ecological Processes and Management Potential.* (Eds. R.E. Good, D.F. Whigham and R.L. Simpson). Academic Press, New York, 341-355.

McLaren, I.A. (1963) Effect of temperature on growth of the zooplankton and the adaptative value of vertical irrigation. *J. Fish. Res. Bd. Canada*, **20**: 685-727.

Mc Laughlin, R.L. and Brindle, I.D. (2001) A Laboratory-scale investigation into the use of powdered iron for *in situ*: Removal of phosphorus from treated sewage effluent with constructed wetlands. *Water Qual. Res. J.* Canada, **36**(4): 759-779.

Melone, G. Ricci, C. and Segers, H. (1998) The trophi of Bdelloidea (Rotifera): A comparative study across the class. *Can. J. Zool.*, **76**: 1755-1765.

Menzel, D.W. and Ryther, J.H. (1961) Annual variation in primary production of the Sargasso Sea of Bermuda. *Deep Sea Res.*, **7**: 282-288.

Michael, R.G. (1965) *Diurnal Variation of the Plankton Correlated with Physico-Chemical Factors in Three Different Ponds*. Ph.D. Thesis. Calcutta Univ., Calcutta, India, 165pp.

Michael, R.G. (1969) Seasonal trends in physico-chemical factors and plankton of a fresh water fish ponds and their role in fish culture. *Hydrobiologia*, **33**(1): 144-160.

Michael, R.G. and Sharma, B.K. (1988) Indian Cladocera. (*Crustacea*: *Branchiopoda*: *Cladocera*). *Fauna of India and Adjacent Countries Series*. Zoological Survey of India, 262pp.

Miricle, M.R. and Serra, M. (1989) Salinity and temperature influence in rotifer life history characteristics. *Hydrobiologia*, **186/187**: 81-102.

Mishra, P.C., Dash, M.C. Kar, G.K. and Das, R.C. (1997) Limnological studies in Hirakud reservoir: Physico-chemical characteristics, plankton density and diversity and water quality index. *In. Recent Advances in Ecobiological Research*. (Ed. M.P. Sinha). A.P.H. Publishing Corporation, New Delhi, 51-63.

Mitra, G.N. and Mahapatra, P. (1956) On the role of zooplankton in the nutrition of carp fry. *India J. Fish.*, **3**(2): 299-310.

Mitscher, W.J. and Gosselink, J.G. (1993) *Wetlands*. 2nd Ed. Van Nostrand-Reinhold, NewYork.

Mitscher, W.J., Mitsch, R.H. and Turner, R.E. (1994) Wetlands of the old and new worlds: Ecology and management . *In. Global Wetlands*: *Old World and New World*. (Ed. W.J. Mitscher), Elsevier, Amsterdam, 3-56.

Mohan, K.S. (1987) Chemistry of two freshwater lakes of Hyderabad, India, Silicates *Poll. Res.*, **6**: 69-72.

Mohanty, R.K. (2000) Activated microbial suspension and nitrogen control in aquaculture system. *Fishing Chimes*, **20**(9): 50-51.

Moitra, S.K. and Mukherji, S.K. (1972) Studies on the freshwater plankton of a fish pond in Kalyani, W. Bengal, India. *Vest. Cesk Spol. Zool.*, **34**: 23-28.

Molot, L.A. and Dillon, P.J. (1991) N : P ratios and the prediction of chlorophyll in phosphorous-limited lakes. *Can. J. Fish. Aquat. Sci.*, **46**: 471-1175.

Moore, D.R.J. and Keddy, P.A. (1989) The relationship between species richness and standing crop in wetlands: the importance of scale. *Vegetation*, **79**: 1-2.

Moore, D.R.J., Keddy, P.A., Gudet, C.L. and Wisheu, I.C. (1989) Conservation of wetlands: Do infertile wetlands deserve a high priority? *Biol. Conserv.*, **47**: 203-217.

Mortimer, C.H. (1939) The work of the freshwater biological association of Great Britain in regard to water supplies: The nitrogen balance of large bodies of water. *Off. Ciarc. Br. Wat. Wes. Ass.*, **21**: 1-10.

Mortimer, C.H. (1941) The exchange of dissolved substances between mud and water in lakes. *J. Ecol.*, **29**: 280-329.

Moss, B. (1969) Vertical heterogeneity in the water column of Abbot's pond. I. The distribution of temperature and dissolved oxygen. *J. Ecol.*, **57**: 381-396.

Moss, B. (1979) Algal and other fossil evidence for major changes in strumpshaw Broadland, Norfolk, England, in the last two centuries. *British Phycolo. J.*, **14**: 263-283.

Moss, B. (1983) The Norfolk Broadland: Experiments in the restoration of a complex wetland. *Biol. Review*, **58**: 521-561.

Moss, B. Bales, M. and Irvine, K. (1991) Food web and water quality relationships in Saline Broads of the River Thurne, Norfolk, *Mem. Ist. Ital. Idrobiol.*, **48**: 345-362.

Moyle, J.B. (1949) *Limnology of Water Supply Waste Disposal*. American Ass. Adv. Science.

Mukherjee, B. Tetarway, S., Pati, M., Prasad, T., Mukherjee, M. and Dhar, S. (1990) Carbondioxide dynamics and metabolic rhythm in polluted aquatic body at Ranchi. *J. Eco. Biol.*, **2**(2): 145-154.

Munawar, M. (1966) *Limnological studies in certain polluted and unpolluted ponds of Hyderabad, India*. Ph.D. Thesis. Osmania Univ., India, 173pp.

Munawar, M. (1970) Limnological studies on freshwater ponds of Hyderabad, India. I. Biotope. *Hydrobiologia*, **35**(1): 127-162.

Munawar, M. (1970a) Limnological studies on freshwater ponds of Hyderabad, India. II. The Biocoenose: The distribution of unicellular and colonial phytoplankton in the polluted and the unpolluted environments. *Hydrobiologia*, **36**: 105-128.

Munawar, M. (1972) Ecological studies of euglenineal in certain polluted and unpolluted environments. *Hydrobiologia*, **39**(3): 307-320.

Munawar, M. (1974). Limological studies on freshwater ponds of Hyderabad, India. IV. The Biocenose: Periodicity and species composition of unicellular and colonial phytoplankton in polluted and unpolluted environments. *Hydrobiologia*, **45**(1): 1-32.

Munawar, M. and Zafar, A.R. (1967) A preliminary study of vertical movement of *Eudorina elagans* and *Trinema linear* during a bloom caused by them. *Hydrobiologia*, **20**(1-2): 140-148.

Mc Laughlin, R.L. and Brindle, I.D. (2001) A Laboratory-scale investigation into the use of powdered iron for *In situ*, removal of phosphorus from treated sewage effluent with constructed wetlands. *Water Qual. Res. J.* Canada, **36**(4): 759-779.

Narayanan, A.K. (1992) Overall strategy being adopted at the government level to encourage conservation of important wetlands of India. *In. Wetlands of India.* (Ed. K.J.S. Chatrath). Ashish Publishing House, New Delhi, India,16-36.

Narendra Rao, V. and Mahmood, S.K. (1995) Nutrient status and biological characteristics of Hybshiguda Pond. *J. Envi. Poll.* **2**(1): 31-34.

Nasar, S.A.K. and Munshi, J.S.D. (1975) Studies on primary production in a freshwater pond. *Jap. J. Ecol.*, **25**: 21-23.

Nautiyal, P. (1984) Studies on riverine ecology of torrential waters in the uplands of the Garhwal region. II. Seasonal fluctuations in diatoms density. *Proc. Indian Acad. Sci.*, (Sec. B) **93**(7): 671-674.

Nayar, C.K.G. (1965) Taxonomic notes on the Indian species of *Keratella* (Rotifers), *Hydrobiologia*, **26**: 457-462.

Nayar, C.K.G. (1971) Cladocera of Rajasthan, India. *Hydrobiologia*, **37**: 509-519.

Needham, J.G. and Needham, P.R. (1962) *A Guide to the Study of the Freshwater Biology*. Holden-Dey Inc., Francisco, 108pp.

Negrea, S., Botnariuc, N. and Dumont, H.J. (1999) Phylogeny, evolution and classification of the Branchiopoda (Crustacea). *Hydrobiologia*, **412**: 191-212.

Neilsen, S.E. and Jensen, A.B. (1957) Primary oceanic production: The production of organic matter in the oceans. *Galathea Rep.*, **1**: 49-135.

Nicklisch, A. and Kohl, J.G. (1983) Growth kinetics of *Microcystis aeruginosa* (Kutz.) Kutz. as a basis for modelling its population dynamics. *Int. Rev. Ges. Hydrobiology*, **68**: 317-326.

Nogrady, T., Wallace, R.L. and Snell, T.W. (1993) *Rotifera.* I. Biology, Ecology and Systematics. *In. Guide to the Identification of the Microinvertebrates of the Continental Waters of the World.* (Eds. H.J. Dumont and T. Nogrady). SPB Academic Piblishers, Amsterdam, The Netherlands, **4**: 1-142.

Northcote, T.G. and Larkin, P.A. (1956) Indices of productivity in British Columbia Lakes. *J. Fish. Res. Bd. Canada*, **13**(4): 515-540.

NWWG (National Wetlands Working Group) (1988) *Wetlands of Canada: Ecological Land Classification Series, Number 24.* Sustainable Development Branch, Environment Canada, Ottawa, Ontario and Polyscience Publications, Montreal, Quebec, Canada.

Odum, E.P. (1971) *Fundamentals of Ecology*. W.B. Saunders Company, Philadelphia, 574pp.

OECD (Organization for Economic Cooperation and Development) (1982) Eutrophication of waters: Monitoring assessment and control. Final report OECD, Cooperative Programme on Monitoring of Inland Waters (Eutrophication Control). Environmental Directorate, OECD, Paris, 154pp.

Ohle, W. (1935) Organische kolloide in three wirking auf den stoffhaushalt aer Gewasser. *Naturwissenschaften*, **23**: 480-484.

Ohle, W. (1938) Die Bedeutung der Austansch Vorgange Zwischen Schalamn and Wasser fur den Stoffkreislauf der Gewasser. "Vom Wasser".

Olesen, J. (1998) A phylogenetic analysis of the Conchostraca and Cladocera (Crustacea, Diplostraca). *Zool. J. Linn. Soc.*, **122**: 491-536.

OMNREC (Ontario Ministry of Natural Resources and Environment Canada) (1984) *An Evaluation System for Wetlands of Ontario South of the Precambrian Shield*. 2nd ed. Wildlife Branch of Ontario Ministry of Natural Resources and Canadian Wildlife Service, Environment Canada, Toronto, Ontario, Canada.

Oxfod Dictionary (1990) The concise oxford Dictionary, Oxford University Press, Delhi, 1662pp.

Paerl, H. and Ustach, J.F. (1982) Blue-green algal scums: An explanation for their occurance during freshwater blooms. *Limnol. Oceanogr.*, **27**: 212-217.

Pagani, M., Ricci, C. and Redi, C.A. (1993) Oogenesis in *Macrotrachela quadricornifera* (Rotifera - Bedelloida). I. Germarium eutely, Karyotype and DNA content. *Hydrobiologia*, **225/256**: 225-230.

Pai, I.K. (2002) Zooplankton as pollution indicator. *In. Ecology of Polluted Waters*. Vol. 2. (Ed. A. Kumar), A.P.H. Publishing Corporation, New Delhi, 827-831.

Palmer, C.M. (1969) Composition rating of algae tolerating organic pollution. *J. Phycol.*, **5**: 78-82.

Panday, S.N. and Tripathi, A.K. (1988) Studies on algae of polluted ponds of Kanpur. V. Effect of water temperature on algal growth. *Proc. Nat. Acad. Sci. India*, **58**(3): 111-115.

Patalas, K. (1972) Crustacean plankton and the eutrophication of St. Lawrence Great Lake. *J. Fish. Res. Bd. Canada*, **29**: 1451-1462.

Patil, C. S. and Goudar, B.Y.M. (1985) Ecological study of freshwater zooplankton of a subtropical pond (Karnataka, India). *Int. Revue. Ges. Hydrobiol.*, **70**: 279-287.

Patrick, R. (1949) A proposed biological measure of stream conditions based on a survey of the Conestoga Basin. Lancaster Country, Pennsylvania. *Proc. of the Academy of Natural Sciences of Philadelphia, P.A., U.S.A.*, **101**: 277-341.

Patric, R. (1969) Some effects of temperature on freshwater algae. *In. Biological Aspects of Thermal Pollution.* (Eds. D.A. Kerenkel and F.L. Parker) Vandervilt. Univ. Press, Naushvilla, Tenn., 161-217.

Patrick, R. (1977) Ecology of freshwater diatoms and diatom communities. *In. The Biology of Diatoms.* (Ed. R. Patrick), Blackwell, London, 284-332.

Patten, B.C., Jorgensen, S.E., Dumont, H.J., Gopal, B., Koryavov, P., Kvet, J., Loffler, H., Sverizhev, Y. and Tundisi, J.G. (1990) *Wetlands and Continental Shallow Water Bodies.* SPB Academic Publishing, The Hague, 759pp.

Paul, R. and Verma, S. (1999) Hydrobiological studies of a tropical standing water body with special reference to nutrient status and primary production. *In. Fresh water Ecosystem of India.* (Ed. K. Vijaykumar). Daya Publishing House, Delhi, 255-286.

Pearsall, W.H. (1923) A theory of diatom periodicity. *J. Ecol.*, **9**: 241-253.

Pearsall, W. H. (1932) Phytoplankton in the English Lakes. II. The proporations in the water of some dissolved substances. *J. Ecol.*, **20**: 241-262.

Pedric, C. (1994) *Water Crisis.* WNL, New Sprint.

Peelan, R. (1974) Data on temperature, oxygen, sediment and transparency of the water in the Northern part of the Delta area of the Netherlands between 1961 and 1972. *Hydrobiol.*, **45**(1): 115-134.

Pejler, B. (1957) Taxonomical and ecological studies on planktonic rotatoria from central Sweden. *K. Svenska Vetensk Akad. Handl.*, **6**: 7-52.

Pejler, B. (1983) Zooplankton indicators of trophy and their food. *Hydrobiologia*, **101**: 111-114.

Pennak, R.W. (1949) Annual limnological cycles in some Colorado reservoir lakes. **19**: 233-267.

Pennak, R.W. (1978) *Freshwater Invertebrates of United States.* 2nd Ed. Johan Wiley & Sons Inc., New York, 803pp.

Pennock, J.R. (1985) Chlorophyll distributions in the Delaware Estuary: Regulation by Light limitation. *Estuarine, Coastal Shelf Sci.*, **21**: 711-725.

Phillipose, M.T. (1959) *Chlorococcales.* Indian council of Agicultural Research, New Delhi, Publication.

Phillipose, M.T. (1960) Freshwater phytoplankton of inland fisheries. *Proc. Symp. on Algology, ICAR,* New Delhi, 272-291.

Phillips, G.L., Eminson, D. and Moss, B. (1978). A mechanism to account for macrophyte decline in progressively eutrophicated freshwaters. *Aquatic Botany*, **4**: 103-126.

Phinney, H.K. and McIntire, C.D. (1965) Effect of temperature on metabolism of periphyton communities development in laboratory streams. *Limnol. Oceanogr.*, **10**(3): 341-344.

Pierce, J.W., Correll, D.L. Goldberg, B., Faust, M.A. and Klein, W.H. (1986) Response of underwater light transmittance in the Rhode River Estuary to changes in water-quality parameters. *Estuaries,* **9**: 169-178.

Pirot, J.Y., Meynell, P.J. and Elder, D. (2000) *Ecosystem Management: Lessons from Around the World: A Guide for Development and Conservation Practitioners.* IUCN, Gland, Switzerland and Cambridge, UK, 132pp.

Pollock, M.M. (1995) *Patterns of Plant Species Richness in Emergent and Forested Wetlands of Southeast Alaska.* Dissertation. University of Washington, Seattle Washington, USA.

Pomeroy, L.R., Smith, E.E. and Grant, C.N. (1965) The exchange of phosphate between estuarine water and sediments. *Limnol. Oceanogr.*, **10**(2): 167-172.

Pontin, R.M. (1978) A key to freshwater planktonic and semi-planktonic *Rotifera* of British Isles. *Freshwat. Biol. Assoc. Sci. Publ.*, **38**: 1-178.

Pouria, S.A., Andrade, A., Barbosa, J., Cavalcanti, L., Barreto, V., Ward, C.J., Preiser, W., Poon, G.K., Neild, G.H. and Codd, G.A. (1998) Fatal *Microcystis* intoxication in haemodialysis unit in Caruaru, Brazil. *The Lancet*, **352**: 21-26.

Prakash, S. Ansari, K.K. and Sinha, M. (2001) Seasonal dynamics of zooplankton in a freshwater pond developed from the wasteland of Brick-Kiln. *Poll Res.*, **20**(4): 681-683.

Prasad, D.Y. (1990) Primary productivity and energy flow in Upper Lake, Bhopal. *Ind. J. Environ. Hlth.*, **32**(2): 132-139.

Prasad, R.R. and Nair, P.V.R. (1963) Studies on organic production. I. Gulf of Mannar. *J. Mar. Biol. Ass. India*, **5**: 1-26.

Prescott, G.W. (1951) *Algae of the Western Great lakes.* Institute of Science Bull., 31. Bloomfield Hills Michigan, Crambrook, 946pp.

Pressey, R.L. and Adam, P. (1995). A review of wetland inventory and classification in Australia. *In. Wetlands of the World. I. Inventory, Ecology and Management*. (Eds. D.J. Whigham, D. Dykyova and S. Heijny). Kluwer Academic Publishers, Dordrecht, The Netherlands, 81-101.

Proctor, V.W. (1959) Dispersal of fresh water algae by migatory water birds. *Sci.*, **130**: 623-624.

Pruthi, H.S. (1933) Studies on the bionomics of freshwaters of India. I. Seasonal changes in the physical and chemical condtions of the water of the tank in Indian Museum Compound. *Int. Rev. Hydrobiol.*, **28**: 46-47.

Qadri, M.Y. and Mustafa, S.G. (1984) Hydrobiological features of Hokarsar: A typical wetland of Kashmir. I. Biotope. *Indian J. Ecol.*, **11**(2): 203-206.

Qadri, M.Y. and Yousuf, A.R. (1978) Seasonal variations in the physico-chemical factors of a subtropical lake of Kashmir. *J. Inland Fish. Soc. India*, **10**: 89-96.

Qadri, M.Y. and Yousuf, A.R. (1980) Limnological studies on lake Malpur. *Geobios*, **7**: 117-119.

Qin, B. (1999) Hydrodynamics of lake Taihu, China. *Ambio.*, **28**: 669-673.

Racey, G.D., Harris, A.G., Jeglum, J.K., Foster, R.F. and Wickware, G.M. (1996) Terrestrial and wetland ecosites of Northeweastern Ontario, Ontario Ministry of Natural resources, Thunder Bay, Ontario, Canada NWST Field guide. FG-02.

Raina, V., Shah, A.R. and Ahmad, S.R. (1984) Pollution studies of river Jehlum. I. An assessment of water quality. *Indian J. Environ. Hlth.*, **26**(3): 187-201.

Rajendran, M. (1973) Copepoda. *In. A Guide to the Freshwater Organisms*. (Ed. R.G. Michael). *J. Madurai Univ. Suppl.*, **1**: 103-151.

Raju, K.R. and Durani, P.K. (1996) Nano-planktonic production in temple ponds of Bhubaneshwar. *J. Environ. Biol.*, **17**(4): 317-320.

Ramamirthan, C.P. (1968) Vertical distribution of temperature, salinity and dissolved oxygen in the Maldives region of Indian Ocean. *Indian J. Fish.*, **15**(1): 27-29.

Ramanibai, P.S. and Ravichandran, S. (1987) Limnology of an urban pond at Madras, India. *Poll. Res.*, **6**: 77-81.

Ramsar Convention Bureau (1997) *The Ramsar Convention Manual: A Guide to the Convention on Wetlands*. (Ramsar, Iran, 1971). 2nd Ed., Ramsar Convention Bureau, Gland, Switzerland.

Rana, B.C. and Nirmalkumar, J.I. (1993) A Composite rating of trophic status of certain ponds of Gujarat, India. *J. Envi. Biol.*, **14**(2): 113-120.

Rangarajan, K. and Marichamy, R. (1972) Seasonal changes in the temperature salinity and plankton volume at Port Blair, Andamans. *Indian J. Fish.*, **19**(1-2): 60-69.

Rao, D.S. and Govind, B.V. (1964) Hydrology of Tungabhadra Reservoir. *Indian J. Fish.*, **11**(1): 321-344.

Rao, D.S., Shakuntala, K., Jayaraj, E.G. and Reddy, S.R. (1999) Limnology and status of the fishery of Nelligudda Reservoir, Bangalore, India. *Indian J. Fish.*, **46**(3): 251-264.

Rao, K. and Mohan, P.C. (1977) *Rotifers as indicators of pollution. Curr. Sci.* **46**: 190pp.

Rao, V.N. and Mahmood, S.K. (1995) Nutrient status and biological characteristics of Hubsiguda Pond. *J. Envi. Poll.*, **2**(1): 31-34.

Rao, V.N., Hariprasad, V. and Ramasubramnian, R. (1993) Seasonal dynamics of physico-chemical factors in a tropical high altitude lake: An assessment in relation to phytoplankton. *J. Envi. Biol.*, **14**(1): 63-76.

Rashid, M.A. (1993) Wetlands and waterfowl conservation in Bangladesh. *In. Wetlands and Waterfowl Conservation in South and West Asia*. Proceedings of International Symposium, Karachi, Pakistan 14-20 December, 1991 (Eds. M. Moser and Jvan Vessem). IWRB Special Publication No. 25, AWB Publication No. 85, IWRB, Slimbridge, UK and AWB, Kuala Lumpur, Malayasia, 54-56.

Ravera, O. (1996) Zooplankton and trophic state relationships in temperate lakes. *Mem. Ist. Ital. Idrobiol.*, **54**: 195-212.

Ravindra Singh (1990) Correlation between certain physico-chemical parameters and primary productivity of three reservoirs of Vishakhapatnam. *Ecol. Environ. Conserv.*, **5**: 43-45.

Rawson, D.S. (1951) The total mineral content of lake waters. *Ecology*, **32**(4): 669-672.

Rea, N. (1995) South Australia's wetland flora: Intact and best kept that way. *Environment South Australia*, **4**(4): 8pp.

Rea, N. (1998) Biological control: Premises, ecological input and *Mimosa pigra* in the wetlands of Australia's Top End. *Wetl. Ecol. Manage.*, **5**: 227-242.

Rea, N. and Storrs, M.J. (1999) Weed invasion in wetlands of Australia's top end: Reasons and solutions. *Wetland Ecol. Management*, **7**: 47-62.

Reckhow, K.H. and Chapra, S.C. (1983) *Engineering Approach for Lake Management*, Vol. 1. Ann Arbor Science, Butterworth Publishing Co, Woburn, Massachusetts, 340pp.

Reddy, P.M. and Venkateshwarlu, V. (1986) Ecology of algae in the paper mill effluents and their impact on the river Tungabhadra. *J. Environ. Biol.*, **7**(4): 215-223.

Reddy, Y.R. (1994) Copepoda: Diaptomidae. *In. Guides to the Identification of the Macroinvertebrates of the Continental Waters of the World.* Vol. 5. S.P.B. Publishers, The Hague, 221pp.

Reddy, Y.R. (2001) Zooplankton diversity: Freshwater planktonic *Copepoda* with key to common *calanoid* and *cyclopoid* genera in India. *In. Water Quality Assessment Biomonitoring and Zooplankton Diversity.* (Ed. B.K. Sharma). Ministry of Environment and Forests, Government of India, New Delhi, 174-189.

Reid, G.H. (1961) *Ecology of Inland Waters and Estuaries.* Reinhold Publishing Corp., New York.

Revti, K. (1993) Biology of two temple tanks at Kovur and Tiruninrawur. *Gobios.*, **20**: 100-104.

Ricci, C. (1983) Rotifera or Rotatoria? *Hydrobiologia*, **104**: 1-2.

Righer, F.H. and Peters, R.H. (1995) Sciences and Limnology. *In. Excellence in Ecology.* Vol. 6. (Ed. O. Kinne.). Ecology Institute, Oldendorf/Luke, Germany.

Rodhe, W. (1948) Environmental requirements of freshwater plankton algae: Experimental studies in the ecology of phytoplankton. *Symb. Bot. Upsalien*, **10**(1): 1-149.

Rodhe, W. (1949) The ionic composition of lake waters. *Vern. Int. Ver. Limnol.*, **10**: 377-386.

Rodhe, W. (1958) The primary productivity in Lakes: Some results and restrictions of the C-14 Method. *Rapp. Const. Explor. Mem. Inst. Ital. Idrobiol.*, **18** suppl.: 365-381.

Rohlf, F.J., Akcakaya, H.R. and Ferraro, S.P. (1996) Optimizing composite sampling protocols. *Environ. Sc. Tech.*, **30**: 2899-2905.

Rorslelt, B. (1991). Principal determinants of aquatic macrophytes richness in northern European lake. *Aquatic Botany*, **31**: 173-193.

Round, F.E. (1966) *The Biology of Algae.* Arnold, London.

Ruttner, F. (1963) *Fundamentals of Limnology*. University of Toronto Press, Toronto, 259pp.

Ruttner-Kolisko, A. (1974) Plankton Rotifera: Biology and Taxonomy. *Suppl. Ed. Die Binnengewasser*, **25**: 1-146.

Ruttner-Kolisko, A. (1989) Problems in taxonomy of rotifer exemplified by the *Filinia longiseta-terminalis* complex. *Hydrobiologia,* **186/187**: 291-298.

Ryding, S.O. and Rast, W. (1989) *The Control of Eutrophication of Lakes and Reservoirs*. Vol. 1. UNESCO, Paris and the Parthenon Publishing Group, U.K., 314pp.

Ryther, J.H. (1956) Interrelations between photosynthesis and respiration in the marine flagellate, *Dunaliella Euchlora, Nature,* **178**: 861-862.

Ryther, J.H. and Dunstan, W.M. (1971) Nitrogen, phosphorus and eutrophication in the coastal marine environment. *Science*, **171**: 1008-1013.

Saksena, D.N. and Sharma, S.P. (1981) Zooplankton fauna of some lentic waters of Gwalior. I . Govindsagar, Chhatri tank, Sawarkar Sarovar and Matsya Sarovar. *Environ. India*, **4**: 13-17.

Saksena, S.B. and Adoni, A.D. (1973) Diurnal variations in Sagar Lake, India: Studies in the deep water areas. *Hydrobiologia*, **43**(3-4): 535-543.

Sabu Thomas and Abdul Aziz, P.K. (1996) Spatial and temporal distribution of nutrients in Peppara reservoir: A man made ecosystem on the Western Ghats, South India. *Poll. Res.*, **15**(1): 5-10.

Sahai, R. and Sinha, A.B. (1969) Investigations on bioecology of inland waters of Gorakhpur, India. I. Limnology of Ramgarh Lake. *Hydrobiologia,* **34**: 433-447.

Saha, G.N., Sehagal, K.L. and Mandy, A.C. (1971) Studies on the seasonal and diurnal variations in physico-chemical and biological conditions of a perennial freshwater pond. *J. Inland Fish. Soc., India,* **3**: 80-102.

Sand-Jensen, K. and Borum, J. (1991) Interactions among phytoplankton, periphyton, and macrophytes in temperate freshwaters and estuaries. *Aquat. Bot.*, **41**: 137-175.

Sant'Anna, C.L. and Azevedo, M.T.P. (1995) *Oscillatoriaceae* (*Cyanophyceae*) from Sao Paulo State, Brazil. *Nova Hedwigia*, **60**: 19-58.

Sant'Anna, C.L. and Azevedo, M.T.P. (2000) Contribution to the knowledge of potentially toxic Cyanobacteria from Brazil, *Nova Hedwigia*, **71**: 359-385.

Sarkar, H.L. and Rai, H. (1964) The limnology of Suraj Kund, India. I. Physico-chemical conditions and plankton. *Trans. Amer. Microsc. Soc.*, **83**(2): 260-265.

Sarkar, S.K. (1989) Phosphorous and aquatic ecosystem. *Indian Rev. Life Sci.*, **9**: 227-251.

Sarma, A.L.N. and Patnaik, P.K. (1985) Ecological studies on zooplankton of freshwater ponds inland around Bhubaneshwar. *J. Environ. Biol.*, **6**(4): 245-256.

Sarwar, S.G. (1999) Water quality and periphytic algal component of Anchar Lake, Kashmir. *In. Freshwater Ecosystem of India*. (Ed. K. Vijayakumar). Daya Publishing House, N. Delhi, 237-250pp.

Sas, H. (1989) *Lake Restoration by Reduction of Nutrient Loading: Expectations, Experiences, Extrapolations*. Academia Verlag, Richarz.

Sastry, A.A.R. and Myrland, P. (1960) Distribution of temperature, salinity and density in the Arabian Sea along the South Kerala coast (South India) during the post-monsoon season. *Indian J. Fish.,* **6**: 223-255.

Sather, J. H. and Smith, R.D. (1984). *An Overview of Major Wetland Functions*. U.S. Fish and Wildlife Service, FWS/DBS-84/18, Washington, D.C., 68pp.

Sather, J.H., Smith, R.D. and Larson, J.S. (1990). *National Values of Wetlands. In. Wetlands and Continental Shallow Water Bodies*. (Eds. B.C. Patten, S.E. Jorgensen, H.J. Dumont, B. Gopal, P. Koryavov, J. Kvet, H. Loffler, Y. Sverizhev and J.G. Tundisi). SPB Academic Publishing, The Hague, 373-387.

Sawyer, C.H. (1960) *Chemistry and Sanitry Engineers*. McGraw Hill Book Co., New York.

Saxena, M.M. (1982) Limnological studies of freshwater reservoir, Sardarsamand. Ph.D. Thesis, University of Jodhpur, Jodhpur, India, 122pp.

Schelske, C.L. Stoermer, E.F. and Feldt, E.L. (1971) Nutrients: Phytoplankton productivity and species composition as influenced by upwelling in Lake Michigan. *Proc. 14th. Conf. Great Lakes Res.*, 102-113.

Schelske, C.L. and Stoermer, E.F. (1972) Phosphorous, silica and eutrophication in Lake Michigan. *In. Nutrients and Eutrophication*. (Ed. G.E. Likens). *Am. Soc. Limnol. Oceanogr.*, Lawrence, KS, 157-171.

Schelske, C.L. and Stoermer, E.F. (1972a) Phosphorous, silica depletion and predicted changes in algal quality in Lake Michigan. *Science*, **173**: 423-424.

Scheurs, H. (1992) *Cyanobacterial dominance: Relations to Eutrophication and Lake Morphology*. Ph.D. Thesis. University of Amsterdam, 183pp.

Schindler, D.W. (1971) Light, temperature and oxygen regime of selected lakes in experimental lakes area, North-Western Ontario. *J. Fish. Res. Bd. Canada*, **28**:157-169.

Schindler, D.W. (1987) Detecting ecosystem responses to antropogenic stress. *Can. J. Fish. Aquat. Sci.*, **44**(Suppl. 1): 6-25.

Schindler, D.W. and Nighswander, J.E. (1970) Nutrient supply and primary production in clear lake. Eastern Ontario, Canada. *J. Fish. Res. Bd. Canada*, **27**: 2009pp.

Schwoerbel, J. (1987) *Handbook of Limnology*. Ellis Horwood Limited, West Sussex, O. 191 EB, England 221pp.

Scott, D.A. (1989) Design of wetlands datasheet for database on Ramsar sites: Mimeographed report to Ramsar Convention Bureau, Gland, Switzerland, 41pp.

Scott, D.A. (1989a) *A Directory of Asian Wetlands*. IUCN, Gland, Switzerland and Cambridge, U.K.

Scott, D.A. and Poole, C. (1989) *A Status Overview of Asian Wetlands*. AWB Publication No. 53, Kuala Lumpur, Malaysia.

Seenayya, G. (1971) Ecological studies in the plankton of certain freshwater ponds of Hyderabad, India. I. Physico-chemical complexes. *Hydrobiologia*, **37**(1): 7-31.

Seenayya, G. and Zafar, A.R. (1981) Algal bloom patterns indicating organic pollution. Proc. WHO workshop on Biological indicators and indices of environmental pollution. *Cent. Bd. Pre. Cont. of Poll.*, Delhi, 101-111.

Seetharamaiah, P. (1966) Studies on the ecology of a fresh water pond community. *Hydrobiologia*, **27**: 529-540.

Segers, H. (1995) Rotifera 2. The *Lecanidae* (*Monogononta*). *In. Guides to the Identification of the Macroinvertebrates of the Continental Waters of the World.* (Eds. H.J. Dumont and T. Nogrady). SPB Academic Publishers, Amsterdam, The Netherlands, **2**: 1-226.

Segers, H. (2001) Zoogeography of the Southeast Asian *Rotifera*. *Hydrobiologia*, **446/447**: 233-246.

Selvaraj, C., Murugesan, V.K., Unnithan, V.K. and Manoharan, S. (1994) Fish production potentiality of small reservoirs in Tamilnadu. *J. Inland Fish. Soc. India*, **26**(2): 9-16.

Shapiro, J. (1984) Blue-green dominance in lakes: The role and management significance of pH and CO_2. *Int. Rev. Ges. Hydrobiologia*, **69**: 765-780.

Shardendu and Ambasht, R.S. (1988) Limnological studies of a rural and an urban tropical aquatic ecosystem: Oxygen forms and ionic strength. *Tropical Ecol.* **29**: 98-109.

Sharma, B.K. and Michael, R.G. (1987) Review of taxonomic studies on freshwater Cladocera from India with remark on biogeography. *Hydrobiologia,* **145**: 29-33.

Sharma, B.K. and Sharma, S. (1999) Freshwater Rotifera (Rotifera: Eurotatoria). *In. Fauna of Meghalaya.* State Fauna Series. *Zool. Surv. India.*, **4**(9): 11-161.

Sharma, B.K, and Sharma, Sumita. (1990) On the taxonomic status of some Cladoceran taxa (Custacea: Cladocera) from Central India. *Rev. Hydrobiol. Trop.*, **23**: 105-133.

Sharma, B.K. (1983) The rotifer community of Mondsee, an alpine lake in Austria. I. Species Diversity and Community Structure. II. Ecology of Planktonic Rotifera. Inst. of Limnology, Austria, Academy of Science, Mondsee, Austria, 80pp.

Sharma, B.K. (1987) Indian *Brachionidae* (Eurotatoria: *Monogononta*) and their distribution. *Hydrobiologia,* **144**: 269-275.

Sharma, B.K. (1990) The genus *Testidunella* (Eurotatoria: Gnesiotrocha: Testudinellidae) in North-Eastern India. *Hydrobiology,* **199**: 29-33.

Sharma, B.K. (1991) Rotifera. *In. Animal Resources of India. Protozoa to Mammalia: State of Art. Zool. Surv. India,* 69-88.

Sharma, B.K. (1991a) Cladocera. *In. Animal Resources of India: Protoza to Mammalia: State of the Art. Zool. Zool. Surv. India.*, 205-223.

Sharma, B.K. (1995) Freshwater Rotifers (*Rotifera: Eurotatoria*): *Fauna of West Bengal: State Faunal Series, Zool. Surv. India,* **3**(13): 1-121.

Sharma, B.K. (1996) Biodiversity of freshwater rotifers in India: A status report. *Proc. Zool. Soc. India,* **49**: 73-85.

Sharma, B.K. (1998) Faunal Diversity in India: Rotifera: *Faunal Diversity of India.* (Eds. J.R.B. Alferd, A.K. Das and A.K. Sanyal). *Zool. Surv. India,* Envis Centre, 57-70.

Sharma, B.K. (2000) Synecology of rotifers in a tropical flood plain lake of upper Assam. *Indian J. Anim. Sci.*, **70**: 880-885.

Sharma, B.K. (2001) Biological monitoring of freshwaters with reference to role of freshwater *Rotifera* as biomonitors. *In. Water Quality Assessment Biomonitoring and Zooplankton Diversity.* (Ed. B.K. Sharma). Ministry of Environment and Forests, Government of India, New Delhi, 83-97.

Sharma, B.K. (2001a) Zooplankton Diversity: Freshwater Planktonic Cladocera (Crustacea: Branchiopoda). *In. Water Quality Assessment Biomonitoring and Zooplankton Diversity*. (Ed. B.K. Sharma). Ministry of Environment and Forests, Government of India, New Delhi, 83-97.

Sharma, B.K. and Sharma, S. (1997) Lecanid rotifers (*Rotifera*: *Monogononta*: *Lecanidae*) of North-Eastern India. *Hydrobiologia*, **356**: 159-163.

Sharma, K.P., Goel, P.K. and Gopal, B. (1978) Limnological studies of polluted freshwater I. Physico-chemical characteristics. *Int. J. Ecol. Environ. Sci.*, **4**: 89-105.

Sharma, P.C. (1980) *Population, Biomass and Energetics of Zooplankton of Kumaun, Lakes*. Ph.D. Thesis. Kumaun Univ., Nainital, India.

Sharma, S.P. and Saksena, D.N. (1981) Zooplankton fauna of some perennial impoundments at Gwalior, India. *J. Jiwaji Univ.*, **9**(1-2): 73-92.

Shastree, N.K., Islam, M.S., Pathak, S. and Afshan, M. (1991) Studies on the physico-chemical dimensions of the lentic hydrosphere of Ravindra Sarovar, Gaya. *In. Current Trends in Limnology*. Vol. 1. (Ed. N.K. Shastree). Narendra Publishing House, Delhi, 133-152.

Shiel, R.J. (1995) A guide to identification of rotifers, cladocerans and copepods from Australian inland waters. Identification Guide No. 3. Co-operative Research Centre for Freshwater Ecology, Albury, NSW, Australia, 1-144.

Shirazi, K. (1993) Wetlands and waterfowl conservation in Pakistan: A national perspestive. *In. Wetlands and Waterfowl Conservation in South and West Asia*. Proceedings of International Symposium, Karachi, Pakistan 14-20 December, 1991. (Eds. M. Moser and Jvan Vessem). IWRB Special Publication No. 25, AWB Publication No. 85, IWRB, Slimbridge, UK and AWB, Kuala Lumpur, Malayasia, 38-40.

Shubert, L.E. (1984) *Algae as Ecological Indicators*. Academic Press, London, England.

Shukla, S.N. and Bais, V.S. (1990) Changes in physico-chemical profile of the Bila reservoir during winter season. *Trends in Ecotoxicology*, 291-293.

Singh, A.K. and Bhowmick, B.N. (1985) Effect of sewage on physico-chemical characteristics and bacterial population of River Ganga at Patna. *Indian J. Ecol.*, **12**(1): 17-19.

Singh, D. N. (2000) Seasonal variation in zooplankton of tropical lake. *Geobios*, **27**: 97-100.

Singh, H.R., Badola, S.P. and Dobriyal, A.K. (1982) Ecology of the river Nayar of Garhwal, Himalaya. *Uttar Pradesh J. Zool.*, **2**: 72-76.

Singh, R.K. (1990) On the seasonal abundance of phytoplankton in relation to ecological condutions of Unda Pond. *Comp. Physiol. Ecol.*, **15**(3): 91-95.

Singh, R.K., Kolerkar, V. and Chandra, R. (1985) Comparative study of certain ecological aspects of river Brahmaputra and Dighalibed in Assam. *Proc. Nat. Acad. Sci. India*, **B55**(2): 21-30.

Singh, U.N. and Pandey, S. (1991) Water quality of stagnant water bodies of north Bihar. *Environment & Ecology*, **9**(3): 770-774.

Singh, V.P. (1960) Phytoplankton ecology of the inland waters of Uttar Pradesh. *Proc. Symp. Algology*, ICAR, New Delhi, 243-271.

Singhal, R.N., Swarnjeet and Davies, R.W. (1986) The physico-chemical environment and the plankton of managed ponds in Haryana, India. *Proc. Indian Acad. Sci.*, (Sec. B) **95**(3): 353-363.

Singhal, R.N., Jeet, S. and Davies, R.W. (1985) The relationship among physical, chemical and plankton characteristics of unregulated rural ponds in Haryana, India. *Trop. Ecol.*, **26**: 43-54.

Singhal, R.N., Jeet, S. and Davies, R.W. (1986) The physico-chemical environment and the plankton of managed rural ponds in Haryana, India. *Pro. Indian Acad. Sci. (Anim. Sci.)*, **95**(3): 353-363.

Sinha, C. and Khan, R.A. (1998) Ecology and diversity of cladocerans in some Calcutta wetlands. *Proc. Nat. Seminar on Envir. Biol. on Biodiversity and Environment*, 154-164.

Sinha, M.K., Pandit, N., Saha, L.C. and Dattamunshi. J. (1992) Comparative limnological study of two religious ponds, Papharni and Sankhkund of Mandar Hill, Bonsi, Bhagalpur, Bihar. *J. Freshwater Biology*, **4**(4): 255-260.

Sinha, R.K. (2001) Biomonitoring of Freshwater ecosystem. *In. Water Quality Biomointoring and Assessment Diversity*. (Ed. B.K. Sharma). Ministry of Environment and Forest, New Delhi, 111-117.

Sivanappan, R.K. (1990) Economic evaluation of tanks. Paper presented at seminar on traditional water harvesting systems of India, New Delhi, October 9-11.

Sladecek, V. (1979) Continental systems for the assessment of river water quality. *In. Biological Indicatiors of Water Quality*. (Eds. A. James and L. Evison). John Wiley & Sons Inc., New York.

Sladecek, V. (1983) Rotifers as indicators of water quality. *Hydrobiologia*, **100**: 169-201.

Small, L.F. (1963) Effect of wind on the distribution of the chloropyll 'a' in clear lakes, Jawa. *Limnol. Oceanogr.*, **8**(4): 462-432.

Smirnov, N.N. (1976) World Macrothricidae and Oinidae (in Russian). Fauna USSR. *Zool. Inst. Acad. Nauk. USSR, New Ser.*, **112**: 1-237.

Smith, S.H. (1962) Temperature correction in conductivity measurements. *Limnol. Oceanogr.* **7**: 330-334.

Smith, V.H. (1982) The nitrogen and phosphorus dependence of algal biomass in lakes: An empirical and theoretical analysis. *Limnol. Oceanogr.*, **27**: 1101-1112.

Sommer, U. (1984) Population dynamics of three planktonic diatoms in lake Constance. *Holarctic Ecol.*, **7**: 257-261.

Spence, D.H.N. (1967) Factors controlling the distribution of freshwater macrophytes with particular reference to Scottish Lakes. *J. Ecol.*, **55**: 147-170.

Spence, D.H.N. (1976) Light and plant response in freshwater: Light as an ecological factor. Proceedings, 16^{th} Symposium of the British Ecological Society, 1974. Blackwell Sci. Pub., London, 93-133.

Spence, D.H.N. (1982) The zonation of plants in freshwater lakes. *In. Advances in Ecological Research.* (Eds. A. Mactadyen and E.D. Ford). Academic Press, London, U.K, 37-125.

Spindler, K.D. (1971) Dormanzauslošung und Dormanzcharakteristika beim Sũ ßwassercopepoden Cyclops vicinus. *Zool Jahrb Physiol.*, **76**: 139-151.

Sramek-Husek, R., Straskraba, M. and Brtek, J. (1962) Lupenonozci-Branchiopoda. Fauna CSSR, Praha, **16**: 1-470.

Sreenivasan, A. (1964) The limnology, primary productivity and fish production in a tropical pond. *Limnol. Oceanogr.*, **9**(3): 391-396.

Sreenivasan, A. (1965) Limnology of tropical impoundments. III. Limnology and productivity of Amravathy Reservoir, Madras, India. *Hydrobiologia*, **26**: 501-516.

Sreenivasan, A. (1970) Limnology of tropical impoundments: A comparative study of the major reservoirs in Madras, India. *Hydrobiologia*, **36**: 443-469.

Sreenivasan, A. (1971a) Shallow aquatic biotopes as limnological models. *Hydrobiologia*, **37**: 553-564.

Sreenivasan, A. (1971b) Seasonal variations in primary productuion in the three ponds. *Hydrobiologia*, **38**: 395-408.

Sreenivasan, A. (1972) Energy transformation through primary productivity and fish production in some tropical freshwaters. *In. Producitivity Problems of Freshwater*. Proc. IBP-UNESCO symposium on productivity problems of freshwater, Kazimierz-Dolny, Poland, 1970.

Sreenivasan, A. (1974) Limnological features of a tropical impoundment, Bhavanisagar Reservoir, T. Nadu, India. *Int. Revue. Ges. Hydrobiol.*, **59**: 327-332.

Sreenivasan, A. (1974): Limnological factors of a tropical impoundment, Odathurai tank. *J. Inland Fish. Soc.* India: **4**: 162-168.

Sreenivasan, A. Sounderaraj, R. and Antomy, F. (1964) Limnological studies of tropical impoundments. II. Hydrological features and plankton of Bhavani Sagar Reservoir, Madras for 1960-61. *Proc. Nat. Acad. Sci. India*, **59**(B): 53-71.

Srivastava, C.B.L. (2000) *A Text Book of Fishery Science and Fisheries*. Kitab Mahal, 22/A, S.N. Marg, Allahabad, India, 527pp.

Starobogator, I.N. (1986) The system of Crustacea. *Zool. Zh.*, **65**: 1769-1781 (in Russian).

Stemberger, R.S. and Gilbert, J.J. (1985) Body size, food concentration and population growth in planktonic rotifer. *Ecology*, **66**: 1151-1159.

Stephens, K. and Strickland, J.D.H. (1962) Use of a thermopile for measuring the attenuation of photosynthetically active radation in the sea. *Limnol. Oceanogr.*, **7**: 485-487.

Stoermer, E.F. (1984) Qualitative characteristics of phytoplankton assemblages. *In. Algae as Ecological Indicators*. (Ed. L.E. Shubert). Academic Press, London, England.

Strickland, J.D.H. (1958) Solar radation penetrating the ocean: A review of requirments, data and methods of measurements, with particular reference to photosynthetic productivity. *J.Fish. Res. Bd. Canada*, **15**: 435-493.

Storrs, M.J. and Finlayson, C.M. (1997) Overview of the conservation status of wetlands of the Nothern Territory. Supervising Scientist Report 123, Supervising Scientist Group, Jabiru, Australia.

Strickland, J.D.H. (1960) Measuring the production of marine phytoplankton. *Bull. Fish. Res. Ed. of Can.*, **122**: 172pp.

Strickland, J.D.H. and Parsons, T.R. (1972) *A Practical Handbook of Sea Water Analysis*, 2nd Ed. *Bull. Fish. Res. Bd.Canada*, **167**: 310pp.

Strom, K.M. (1927-1928) Recent Advances in Limnology. *Proc. Limn. Soc. Lond.*, **140**: 96-110.

Subba Rao, D.V. and Govind, B. (1964) Hydrobiology of Tungabhadra Reservoir. *Indian J.Fish.*, **11**: 321-344.

Sugunan, V.V. (1995) Reservior fisheries of India. FAO, Rome Italy. *Fisheries Technical Paper*, 345, Rome, FAO, 423pp.

Sugunan, V.V. (1997) Floodplain wetlands, small water bodies, culture-based fisheries and enhancement-conceptual framework and definitions. *In. Fisheries Enhancement in Small Reservoirs and Flood-plains Lakes in India.* (Ed. V.V. Sugunan). Bulletin No. 75, CICFRI, Barrackpore, India.

Sukumaran, P.K. and Das, A.K. (2001) Distribution of plankton in some freshwater reservoirs of Karnataka. *J. Inland Fish. Soc. India*, **33**(2): 29-36.

Sumitra, V. (1969) *Limnological Studies of Some Tropical Ponds.* Ph.D. Thesis. Madurai Univ., India.

Sverdrup, H.U., Johnson, M.W. and Fleming, R.H. (1962) *The Oceans: Their Physics, Chemistry and General Biology.* Asia Publishing House, Bombay.

Swar, K. and Fernando, C.H. (1980) Effect of environmental factors on zooplankton. *Arch. Hydrobiol.*, **26**: 310-321.

Swarbrick, J.T, Finlayson, C.M. and Cauldwell, A.J. (1982) The biology and control of *Hydrilla verticillata.* Biotrop Special Publication No. 16, Bogor, Indonesia, 34pp.

Swarup, K. and Singh, S.R. (1979) *J. Inland Fish. Soc., India*, **11**: 22-33.

Sweeney, B.W. (1976) A diurnally fluctuating thermal system for studying the effect of temperature on aquatic organisms. *Limnol. Oceanogr.*, **21**(5): 758-763.

Swingle, H.S. (1967) Standardization of chemical analysis for water and pond mud. *FAO. Fish. Rep.*, **44**(4): 397-421.

Szyper, J.P. and Lin, C.K. (1990) Techniques for assessment of stratification and effects of mechanical mixing in tropical fish ponds. *Aquaculture Engineering*, **9**: 151-165.

Talling, J.F. (1957) The longitudinal sucession of water characteristics in the White Nile. *Hydrobiologia*, **11**: 73-89.

Talling, J.F. (1965) Comparative problem of phytoplankton production and photosynthetic productivity in a tropical and a trmperate lake. *Mem. Ist. Ital. Idrobiol.*, **18**: 399-424.

Talling, J.F. (1976) The depletion of carbon dioxide from lake water by phytoplankton. *J. Ecol.*, **64**: 79-121.

Talwar, P.K. and Jhingran, A.G. (1991) *Indian Fisheries of India and Adjacent Countries.* (I and II). Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 1097pp.

Tandon K.K. and Singh, H. (1972) Effect of certain physico-chemical factors on the plankton of the Nangal Lake. *Proc. Indian Acad. Sci.*, **76**: 15-25.

Tarzwell, C.M. (1957) Biological problems in water pollution. U.S. Deptt. of Health Education and Welfare. P.H.S., 246-272.

Theroux, F.R., Eldridge, E.F. and Mallmann, W.L. (1943) *Laboratory Manual for Chemical and Bacterial Analysis of Water and Sewage.* McGraw Hill Book Co. Inc., New York, 267pp.

Thomas, S. and Abdul Aziz, P.K. (1996) Spatial and temporal distribution of nutrients in Pappara Reservoir: A man-made ecosystem on the Western Ghats, South India. *Poll. Res.*, **15**(1): 5-10.

Thompson, M.J., Gilliland, L.E. and Rosenfield, L.K. (1979) Light scattering and extinction in a highly turbid coastal inlet. *Estuaries*, **2**: 164-171.

Thorpe, T and Lloyd, B. (1999) The macroinvertebrate fauna of St. Lucia elucidated by canonical correspondence analysis. *Hydrobiologia*, **400**: 195-203.

Thresh, J.C., Suckling, E.V., and Beale, J.F. (1994) *The Examination of Water and Water Supplies.*

Thukral, A.K., Joshi, M.C. and Chand, R. (1983) Physico-chemical characteristics of tailings sediment for Khetri Copper Complex. *Indian J. Environ. Hlth.*, **25**(2): 120-127.

Tinner, R.W. (1984) *Wetlands of the United States: Current Status and Trends.* US Fish and Wildlife Service.

Toetz, D.W. (1971) Diurnal uptake of NO_3 and NH_3 by *Ceratophyllum* - periphyton community. *Limnol. Oceanogr.*, **16**: 819-822.

Tonapi, G.T. (1980) *Freshwater Animals of India: An Ecological Approach.* Oxford and IBH Publishing Co., New Delhi, India. 341pp.

Toner, M. and Keddy, P. (1997) River hydrology and riparian wetlands: A predictive model for ecology assembly. *Ecol. Applications*, 7(1): 236-246.

Tripathi, A.K. Pandey, S.N. and Tiwari, R.K. (1987) Eutrophication study of Kalyanpur Pond, Kanpur, India. *Proc. Nat. Acad. Sci.*, India, **57**(B)(III): 279-283.

Tripathi, R.S. and Srivastava, V.M.S. (1985) Hydrochemical studies of selected water bodies of the carpet belt of eastern U.P. India. *Acta Hydrochim. Hydrobiol.*, **13**(3): 359-370.

Trisal, C.L. (1992) Anthropogenic pressure and management of Dal Lake, Kashmir. *In. Wetlands Of India.* (Ed. K.J.S. Chatrath). Ashish Publishing House, New Delhi, India,71-102.

Trisal, C.L. (1993) Conservation of wetlands in India and international treaties. *In. Wetlands and Waterfowl Conservation in South and West Asia.* Proceedings of International Symposium, Karachi, Pakistan 14-20 December, 1991 (Eds. M.Moser and Jvan Vessem) IWRB Special ublication No. 25, AWB Publication No. 85, IWRB, Slimbridge, UK and AWB, Kuala Lumpur, Malayasia, 41-49.

Trisal, C.L. and Zutshi, D.P. (1985) *Ecology And Management Of Wetland Ecosystem in India.* Paper presented at Regional meeting of National MAB committees of Central and South Asian Countries, March 1985, N.Delhi.27pp.

Trivedy, R.K. (1988) *Ecology and Pollution of Indian Rivers.* Ashish Publishing House, New Delhi, 447pp.

Trivedi, R.K., Garud, J.N. and Goel, P.K. (1985) Studies on chemistry and phytoplankton of a few freshwater bodies in Kohlapur with special reference to human activity. *Poll. Res.*, **4**(1): 25-44.

Trivedi, R.K. and Goel, P.K. (1984) *Chemical and Biological Methods for Water Pollution Studies.* Environmental Publications, Karad, India, 215pp.

Untoo, S.A., Khan, A.A. and Parveen, S. (2001) 200 years old Lal diggi pond at Aligarh approaching towsards grassland ecosystem: A case of an ecological sucession. *Asian J. of Microbiol. Biotech. Eniv. Sc.*, **3**(4): 379-380.

Unni, K.S. (1971) An ecological study of the microphytic vegetation of the Doodhadhari Lake, Raipur, India. II. Physical factors. *Hydrobiologia*, **38**: 479-487.

Unni, K.S. (1972) An ecological study of the microphytic vegetation of the Doodhadhari Lake, Raipur, India. II. Chemical factors. *Hydrobiologia*, **40**: 25-36.

Unni, K.S. (1982) Limnological studies on Sampra Reservior, Betul, M.P. *Proc. Nat. Acad. Sci., India*, **52**(B) IV: 365-372.

Unni, K.S. (1983) Comparative water chemistry of a plankton dominated and a macrophytic dominated lake in Chhindwara, M.P. *Proc. Nat. Acad. Sci.* India, **53**(B): 81-88.

Unni, K.S. (1984) Limnology of a sewage polluted tank in Central India. *Int. Revue. Ges. Hydrobiologia*, **9**: 553-565.

Unni, K.S. (1992) Phytoplankton distribution in the macrophytic community of Govindgarh Lake, Reva, India. *J. Ecobiol.*, **4**: 11-14.

Unni, K.S. (1993) Phytoplankton distribution reservoir and Lakes of India: A review. *Verh. Internat. Varein. Linnol.* **25**: 1262-1265.

Upadhyaya, M.P. (1955) Calcium content of some fishery waters of Uttar Pradesh. *Indian J. Vet. Sci. Anim. Husb.*, **25**(4): 341-346.

Upadhyaya, M.P. (1963) Hydrobiological survey of Gujra Tal, Jaunpur, India. *Labdev.*, **1**: 1-6.

Upadhyaya, M.P. (1964a) Hydrobiological survey of fishery waters of Uttar Pradesh and study of factors responsible for poor growth and survival of fingerlings and fry in tanks and nurseries of U.P. for the year 1960-61 and 1961-62: Progress Report, *Fish. Res. Lab.*, Deptt. of Fish. Gorakhnath Road, Lucknow.

USEPA (1990) Biological criteria. EPA-440/5-90-004, Washington, DC.

USEPA (1991) *Hand book remidatation of contaminated sediments.* EPA-625-91-028 Ctr. For *Environ Res.*, Information Office of Research and Development, Cincinnation, OH.

Usbac, S. and James, R. (1993) A *directory of Important Wetlands in Australia.* Austtralian Nature Conservation Agency, Canberra.

Vaccaro, R.F. (1965) Inorganic nitrogen in sea water. *In. Chemical Oceanography.* (Eds. J.P. Relay and G. Skirrow). Vol.1. Academic Press, London.

Valencha, V. and Bhatnagar, G.P. (1988) Seasonal changes of phytoplankton in relation to some physico-chemical factors in lower lake of Bhopal. *Geobios* **15**: 170-173.

Valencha, V., Trivedy, R. and Bhatnagar, G.P. (1987) Biological assessment of tropical status of Lower Lake of Bhoipal. *Poll. Res.*, **6**: 91-93.

van der Valk, A.G.(1981) Sucession in wetlands: A Gleasonian approach. *Ecology.* **62**: 1150-1164.

van der Valk, A.G.and Davis,C.B. (1978) The role of seed banks in the vegetation dynamics of prairie glacial marshes. *Ecology*, **59**: 322-335.

van der Valk, A.G. and Hilts, S. (1985) *Some Important Wetlands of Ontario Southof the Precambrian Shield.* The Federation of Ontario Naturalists, Don Mills, Ontario.

Vasconcelos, V.M. (1994) Toxic cynobacteria (blue-green algae) in Portuguese freshwaters. *Arch. Hydrobiol.*, **130**: 439-451.

Vasisht, H. S. and Sharma, B.K. (1975) Ecology of a typical urban pond in Ambala City of Haryana, India. *Indian J. Ecol.*, **2**: 79-86.

Vasisht, H. S. and Sharma, B.K. (1976) Seasonal abundance of rotifer population in freshwater pond in Ambala City, Haryana, India. *J. Zool. Soc. India*, **28**: 34-35.

Vasisht, H.S. (1968) Limnological studies of Sukhna Lake, Chandigarh, India. *Proc. Symp. Recent Adv. Trop. Ecol.*, 316-325.

Vass, K.K. (1978) Limnological studies on Dal lake . I. Morphometery and physical features. *J. inland Fish. Soc. India*, **11**: 12-21.

Venkateshwarlu, M. (1983) Taxonomy and ecology of algae in the river Moosi, Hyderabad, India. II. *Bacillariophycea. Bibliotheca Phycologica.* (Ed J. Cramer), **66**: 1-44.

Vernkataraman, K and Das, S.R. (1993) Freshwater cladocera (Crustacacea: Brachioda) of southern W.Bengal. *J. Andaman. Sci. Associ.*, 9 (162): 19-24.

Venkateshwarlu, M. and Hosetti, B.B. (2002) Limnobiology of Shanthi Nagar Pond of B.R. Project. *In*: *Wetlands Conservation and Management*. (Ed. B.B. Hosetti). Pointer Publishers, Jaipur, India, 243-253.

Verity, P.G. and Smetacek, V. (1996) Organism life cycle, predation and the structure of marine pelagic ecosystems. *Mar. Ecol. Prog. Ser.,* **130** : 277-293.

Verma, A. and Sharma, Y. (2002) Hydrobiological studies on freshwater ponds. *In.* Wetlands Conservation and Management (Ed. B.B. Hosetti). Pointer Publishers, Jaipur, India, 254-265.

Verma, A.K. (1964) Studies on the life histories of some terrestrial algae, including a study of the algae of some rice fields. D. Phil. Thesis. Univ. of Allahabad., India.

Verma, M.N. (1969) Hydrobiological study of a tropical impoundment Tekanpur Reservoir, Gwalior, India, with special reference to the breeding of Indian Carp. *Hydrobiologia,* **34**: 358-368.

Verma, S.R. and Shukla, G.R. (1968) Hydrobiological studies of a temple tank Devikund in Deoband, U.P. India. *Indian J. Envi. Hlth.,* **10**: 177-188.

Verma, S.R. and Shukla, G.R. (1970) The physico-chemcial conditions of Kamala Nehru Tank Muzzafarnagar in relation to biological productivity. *Indian J. Environ. Hlth.*, **12**(2): 110-128.

Verma, S.R., Tyagi, A.K. and Dalela, R.C. (1978) Pollution studies of few rivers of Western Uttar Pradesh with reference to biological indicies. **87**(6): 193-198.

Verry, E.S.(1975) Stream flow chemistry and nutrient yields from Upland-Peatland watersheds in Minnesota. *Ecology,* **56**: 1149-1157.

Victor, R. and Fernando, C.H. (1979) The freshwater Ostracoda (Crustacea, Ostracoda) of India. *Rec. Zool. Surv. India*, **74**: 147-242.

Vijayan, V.S. (1986) On conserving the bird fauna of Indian wetlands. *Proc. Indian Acad. Sci.* (*Animal Sci./Plant Sci.*) Suppl., 91-101.

Vijayan, V.S. (1991) *Keoladeo National Park Ecological Study. Summary Report* 1980-1990. *Bomb Nat. Hist. Soc.*, Bombay.

Vijayan, V.S. (1994) *Keoladeo National Park, Rajashtan. Ramsar Sites of India.* **3**: WWF India, N.Delhi.77pp.

Vijayaraghavan, S. (1969) Seasonal events in a natural population of *Daphnia carinata* King. *Proc. Indian Acad. Sci.* **B 70**: 193-198.

Vijaykumar, K. (1992) *Limological Studies of Perennial and Seasonal Standing Water Bodies of Gulbarge Area.* Ph.D. Thesis. Gulbarga University,Gulbarga 160pp.

Vijaykumar, K. (1999) *Freshwater Ecosystems of India.* Daya Publishing House, Delhi, 336pp.

Vijaykumar, K. and Basalingappa, S. (1992) Effect of physico-Chemical factors on seasonal abundance of *Cladocera* in Devikoppa Tank. *J. Karnatak Univ. Sci.*, **34**:135-140.

Vijaykumar, K., Devendra, H. and Kaur, K. (1999) Limnological studies on Chandrampalli Reservior, Gulbarga. *In. Freshwater Ecosystems of India.* (Ed. K. Vijaykumar). Daya Publishing House, Delhi, 59-108.

Vijveberg, J. and Richter, A.F. (1982) Population dynamics and production of *Daphnia hyalina* Leydig and *Daphnia cuculata* Sars in Tyenkemeer. *Hydrobiologia*, **95**: 235-259.

Vollenweider, R.A. (1950) Okologische Lintersuchungen von Planketischen Algen anf experimentalker Grendiangeschweiz. *Z. Hydrol.*, **12**: 194-262.

Vollenweider, R.A. (1968) Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication. *Technical Report DSA/CSI/* 68.27, *Environmental Directorate*, Organisation for Economic Cooperation and Development (OECD), Paris, 154pp.

Vollenweider, R.A. (1969) *Manual of the Methods for Measuring Primary Production in Aquatic Environment.* IPB Handbook No. 12, Blackwell Scientific Publicatioons, Oxford, 213pp.

Von Brand, T. and Rakestraw, N.E. (1940) Decomposition and regeneration of nitrogenous organic matter in sea water. III. Influence of temperature and source and condition of water. *Bio. Bull., Woodes Hole.*, **79**: 231-236.

Von Oye, P. (1934) Quelques donnes sur ecolgie des desmids. *Bull. Roy. Bot. Belg.*, **67**(1): 65-75.

Vyas, L.N. and Kumar, H.D. (1968) Studies on the phytoplankton and other algae of Indira Sagar Tank, Udaipur, India. *Hydrobiologia*, **31**: 421-434.

W.H.O. (World Health Organization) (1984) *Guidelines for Drinking Water Quality: Health Criteria and Other Supporting Information* II. Geneva. ISBN 924-154169-5. 327pp.

Wallace, R.L. and Snell, T.W. (1991) *Rotifera. In. Ecology and Classification of North American Freshwater Invertebrates.* (Eds. S.H. Thorpe and A.P. Covch). American Press, New York, 187-248.

Wanganeo, A. (1984) Primary production characteristics of a Himalayan Lake in Kashmir. *Int. Revue. Ges. Hydrobiol.*, **1**(69): 79-90.

Watanabe, M.F., Harada, K., Carmichael, W.W. and Fujiki, H. (1996) *Toxic Microcystis.* CRC Press, Boca Raton, FL, 262pp.

Watanabe, T. (1970) Studies on application of Cyanophyta in Japan. *Schweiz. Z. Hydrol.*, **32**: 566-569.

Watanabe, T. (1978) Nutrition quality of living feeds used in seed production of fish. *Pro. 7th Japan Soviet Joint Symp. Aquaculture,* 49-57.

Waters, T.F. (1977) Secondary production in inland waters. *Adv. Ecol. Res.*, **10**: 11-164.

Webb, D.G. and Parson, T.R. (1988) Empirical analysis of the effects of temperature on marine harpacticoid copepod development time. *Can. J. Zool.*, **66**(6): 1376-1381.

Webber Jr, W.J. and Stumm (1963) Mechanism of hydrogen ion buffering in natural waters. *J. Amer. Wat. Works Assoc.*, **155**: 1553pp.

Weiher, E., Wisheu, I.C., Keddy, P.A. and Moore, D.R.J. (1996) Establishment, persistence, and management implications of experimental wetland plant communities. *Wetlands*, **16**: 208-218.

Weiher, E. and Keddy, P.A. (1995) The assembly of experimental wetland plant communities. *Oikos*, **73**: 323-335.

Welch, P.S. (1948) *Limnological Methods*. Mc Graw-Hill Book Co. Inc., New York.

Welch, P.S. (1952) *Limology*. Mc Graw-Hill Book Co., Inc., New York, 538 pp.

Werner, D. (1977) *The Biology of Diatoms*. Berkley Univ. California Press, 498pp.

West, W. and West, G.S. (1907) Fresh water algae from Burma including a few from Bengal and Madras. *Ann. Bot. Garden*, Calcutta, **6**(2): 1907pp.

Westlake, D.F., Adams, M.S., Bindloss, M.E., Ganf, G.G., Gerloff, G.C., Hammer, U.T., Javornicky, P., Koorce, J.F., Marker, A.F.H., Mc Cracken, M.D., Moss, B., Naurverck, A., Pyrina, I.L., Steel, J.A.P., Tilzer, M. and Watters, C.J. (1980) Primary production. *In. The Functioning of Freshwater Ecosystems*, (Eds. E.D. Crence and R.H. Mc Connel-Lowe). Cambridge, London, New York, 587pp.

Wetzel, R.G. (1964) A comparative study of the primary productivity of higher aqauatic plants, periphyton and phytoplankton in a large shallow lake. *Int. Ges. Hydrobiol.*, **49**: 1-61.

Wetzel, R.G. (1966) Productivity and nutrient relationship in Marl: Lakes of Northern Indiana. *Verh. Int. Ver. Limnol.*, **16**: 321-332.

Wetzel, R.G. (1975) *Primary Production River Ecology*. Blackwell Scientific Publication, Oxford.

Wetzel, R.G. (1983) *Limnology*. 2nd ed. Saunders College Publishing Co., New York, 767pp.

Wetzel, R.G. and Likens, G.E. (1979) *Limnological Analysis*. W.B. Saunder Co. Philadelphia, 357pp.

Wibowo, P. and Suyatno, N. (1997) An overview of Indonesian wetlands sites. *In. Wetland Database*. Wetlands International-Indonesia Programme/PHPA, Bogor, Indonesia.

Wright, J.F., Furse, M.T. and Armitag, P.D. (1994) Use of macro invertebrate communities to detect environmental stress in running waters. *In. Water Quality and Stress Indicators in Marine and Freshwater Systems: Living Levels of Organization*. (Ed. D.W. Sutcliffe). Freshwater Biological Association, U.K.

Wu, Jiunn-T. (1999) A generic index of diatoms assemblages as bioindicator of pollution in the Keelong River of Taiwan. *Hydrobiologia*, **397**: 79-87.

WWF (1987) World Wide Fund for Nature, India for the Ministry of Environment and Forests, Government of India.

WWF (World Wide Fund) India and AWB (1992). *India's Wetlands Mangrooves and Coral Reefs*. WWF-India for the Ministry of Environment and Forests, Government of India, New Delhi, India, 61pp.

WWF (World Wide Fund) India and AWB (1993). *Directory of Indian Wetlands*. WWF- India, New Delhi and Asian Wetland Bureau, Kuala Lumpur, 264pp.

Yadava, Y.S., Singh, R.K., Choudhuary, M. and Kolekar, V. (1987) Limnology and productivity in Dighali beel (Assam). *Trop. Ecol.*, **28**: 137-146.

Yan, N.D., Keller, W., Somers, K.M., Pawson, T.W. and Girard, R.E. (1996) Recovery of crustacean zooplankton communities from acid and metal contamination: comparing manipulated and reference lakes. *Can. J. Fish. Aquat. Sci.*, **53**: 1301-1327.

Yousuf, A.R., Balkhi, M.H. and Qadri, M.Y. (1984) Summer and winter cladoceran communities of the Anchar lake, Kashmir. *Geobios*, **3**(1): 66-69.

Yousuf, A.R. and Mustafa, S.G. (1988) Comparative limnology of some freshwaters habitats of Kashmir. *Geobios*, **7**: 58-61.

Yousuf, A.R., Mustafa, S.G. and Qadri, M.Y. (1986). Some limnological aspects of MirGund Wetland. *Geobios News Reports*, **5**: 27-30.

Yousuf, A.R., Qadri, M.Y., Mustafa Shah, G. and Naquash, H.A. (1983) Crustacean communities of freshwaters of Kashmir. *J. Ind. Inst. Sci.*, **64**(c): 83-89.

Zarull, A.M.and Mudroch, A. (1993) Remediation of contaminated sediments in Laurentian great Lakes. *Review of Environmental & Toxicology*, **132**: 93-115.

Zafar, A.R. (1959) On the ecology of algae in certain fish ponds of Hyderabad, India. III. The periodicity. *Hydrobiologia.*, **13**(1): 96-112.

Zafar, A.R. (1964) On the ecology of algae in certain fish ponds of Hyderabad, India. II. Distribution of unicellular and colonial forms. *Hydrobiologia*, **24**: 556-566.

Zafar, A.R. (1966) Limnology of Hussain Sagar Lake, Hyderabad, India. *Phykos.*, **5**(1-2): 115-216.

Zafar, A.R. (1967) On the ecology of algae in certain fish ponds of Hyderabad. *In. Proc. Sym. on Recent Advances in Tropical Ecology*. (Eds. R. Misra and B. Gopal). Varanasi, India, 368-375.

Zhou, X.L. and Wangersky, P.J. (1985) Copper complexing capacity in cultures of *Phaeodactylum tricornutum*. *Mar. Chem.*, **17**: 301-312.

Zhou, X.L. and Wangersky, P.J. (1989) Production of Copper complexing organic ligands by marine diatom, *Phaeodactylum tricornutum*, in a cage culture turbidostat. *Mar. Chem.*, **26**: 239-259.

Zhu, S., Wang, S. and Deltour, J. (2000) Modelling thermal stratification in aquaculture ponds. *Asian Fisheries Sciences*, **13**: 169-182.

Zutshi, D.P. (1981) Evaluation of eutrophication in fresh water lakes using phytoplankton and primary production as indicators. Paper presented at WHO workshop on Biological Indicators and Indicies of Environmental Pollution (1981) *Hyd. Osm. Univ., India*, 85-91.

Zutshi, D.P. and Khan, M.A. (1977) Limnological investigation of a two sub-tropical lakes. *Geobios*, **4**: 45-48.

Zutshi, D.P. and Vass, K.K. (1978) Limnological studies on Dal Lake. II. Chemical features. *Indian J. Ecol.* **5**(1): 90-97.

Zutshi, D.P. and Vass, K.K. (1982) Limnological studies on Dal Lake, Srinagar. III. Biological features. *Proc. Indi. Natn. Acad.*, B. **48**(2): 234-241.